Institutional change in fisheries management: what determines the implementation of private property rights?

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Abstract

Establishing private property rights (PPRs) is a broadly advocated policy tool to increase economic efficiency in fisheries management, thereby solving the problems many global fisheries are facing today: decreasing fish stocks, overcapitalization and ecosystem disruption. However, only 10% of global stocks are governed with PPRs, so implementation of PPRs is rather low. Why are so many countries reluctant to adopt PPRs in fisheries? To increase understanding of right based systems in fisheries, this thesis aims to find the determinants of PPR adoption in fisheries management. The effects of three ecological and economic conditions, being the exploitation status of the stock, the type of the fish species and the value of the fish species, on the adoption of PPRs is examined by exploiting a panel data set consisting of 6337 fisheries with observations over the time span 1950-2006. Employing a cross-section study in which different countries are compared to each other may be misleading, as countries may have (unobservable) individual country characteristics. Therefore, a model with country fixed effects, and in some cases additional species fixed effects, is used to analyse the effects within a country. Results from these estimations show that fish species being fully exploited or overfished increase the probability of PPRs being implemented, while collapsed fish stocks have a negative effect on the probability of PPRs being implemented. Evidence is also found that demersal fish species have a positive effect on the probability of PPRs being implemented, contrary to pelagic fish species. Finally, the research showed that the (world) price of fish species has a negative effect on the probability of PPRs being implemented, meaning that higher priced fish species decrease the probability of PPRs being implemented. The findings from this research can support scientists and policy makers to better understand the factors or conditions that determine the adoption of PPRs in fisheries management.

Keywords: common pool resource, fisheries management, private property rights, individual transferable quotas, high-dimensional fixed effects model

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List of Abbreviations

CDQ	Community Development Quota
CFP	Common Fisheries Policy
DiD	Difference-in-difference
EDF	Environmental Defense Fund
EEC	European Economic Community
EEZ	Exclusive economic zone
EU	European Union
GDP	Gross domestic product
HDFE	High-dimensional fixed effects
ICES	International Council for the Exploration of the Sea
IFQ	Individual fishing quota
IQ	Individual quota
ITQ	Individual transferable quota
IV	Instrumental variable
IVQ	Individual vessel quota
MEY	Maximum economic yield
ML	Maximum likelihood
MSY	Maximum sustainable yield
OECD	Organisation for Economic Co-operation and Development
Pp	Percentage point
PPRs	Private property rights
RFMO	Regional fisheries management organisation
SAU	Sea Around Us
SEM	Structural equation modelling
STECF	Scientific, Technical and Economic Committee for Fisheries
TAC	Total allowable catch
TURF	Territorial use rights for fish

UN	United Nations
UNCLOS	United Nations Conference on the Law of the Sea
WWII	World War II

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1. Introduction

1.1 Problem definition

Globally, many fisheries are in crisis, facing decreasing fish stocks, overcapitalization and ecosystem disruption (Grafton, Squires, & Kirkley, 1996; Webster, 2015). The share of overfished fish stocks increased from 10% in 1974 to more than 33% in 2015, with the late 1970s and the 1980s as the period with the largest increases (FAO, 2018). The overexploitation of the fish stocks and the overcapacity of the fishing fleet can be summarized as "too many boats chasing too few fish" (Clark, 2006). In most fisheries, the key driver of these problems is the common-pool resource dynamics (Webster, 2015). Marine fish stocks can be classified as common-pool resources, which are characterized by their non-excludable and rivalrous character. This means that the resources are accessible to all and that the resource extraction of each individual reduces the amount of resource units available to other users (Ostrom, 2008). Assuming that each fisher is rational and will thus maximize his own gain, this situation results in overexploitation of the fish stock, which Hardin (1968) described as the *tragedy of the commons*. It is argued that this common-pool resource problem can be better described as the outcome of insufficient property rights (Arnason, 2012). There is increasing consensus among scholars that the cause of natural resource degradation and the inefficient use of natural resources is in the institutions (Acheson, 2006). The establishment of high-quality private property rights (PPRs) is a broadly advocated policy tool in order to increase economic efficiency in fisheries and thereby solving the main problems of decreasing fish stocks, overcapitalization and ecosystem disruption. There are multiple types of rights based systems in fisheries, such as individual quotas (IQs) individual vessel quotas (IVQs), territorial user right fisheries (TURFs), community development quotas (CDQs) and restrictive licenses, but the most common are the individual transferable quotas (ITQs) (Agnarsson, 2009; Arnason, 2005).

Nevertheless, the use of private property rights as an instrument in natural resource management is also increasingly criticized. Burdon (2010) states that private property rights are 'misleading, morally deficient and contribute significantly to environmental harm' (p. 714). According to Burdon (2010), a private property rights system focuses solely on the self-interest of the property right holder and is adverse to obligations toward the natural resource. Other scholars argue other types of property rights ownership in natural resource management: According to Lovejoy (2006), public ownership of natural resources is the only way to achieve sustainable conservation, while Ostrom (1990) argues that natural resources should be seen as communal property, co-managed by local communities. Ostrom (1990) cautions against privatizing common-pool resources as marine fisheries since it could lead to one individual or one firm having the exclusive right to harvest, thereby decreasing local control of the resource, which could weaken the local community. Other critics argue that public goods as marine fish resources should not be privatised at all out of ideological beliefs, while others believe that institutional change in fisheries management may harm employment in the fishing sector (Agnarsson, 2009). Despite this criticism on PPRs, it is argued that there is not yet a sufficient alternative to a system based on private property rights in fisheries (Hannesson, 2004).

ITQs were first implemented in Iceland in 1979 and in the subsequent decades multiple other countries also made the transition from open access to a rights based system including property rights in their fisheries (Arnason & Runolfsson, 1997). Nowadays, approximately 10% of the global ocean fish harvest is harvested under ITQs (Arnason, 2005). Even though it is widely known that private property rights are effective in solving the problems of overfishing and overcapitalization, only 10% of the global fish harvest is managed by ITQs. So ITQs are seen as the solution to the main problems in marine fisheries, however the broad adoption of ITQs is lagging behind (Heal, 2007). It remains to be seen why ITQs are not adopted more widely in fisheries management.

Research on what explains institutional change, as the adoption of PPRs can be characterized, is not that common: theoretical research on determinants of institutional change is rather limited, and empirical research is even more scarce (Raiser, Tommaso, & Weeks, 2001). While the establishment of informal institutions is often discussed by scholars as Ostrom (1990), research on how and why formal institutions like private property rights are established is rather lacking. Most research on rights based systems in fisheries management assess the effectiveness of the implementation of PPRs by examining the impact of PPRs on ecological outcomes as the stock biomass (Acheson, Apollonio, & Wilson, 2015; Annala, 1996; Miller & Breen, 2016). However, empirical research on the factors that determine the adoption of PPRs is rather lacking. Rather than exploring all determinants of PPR adoption, this study will focus on three potential factors that could determine the adoption of PPRs. These three factors are the exploitation status of the fish stock, the type of the fish species and the value of the fish species. The effects of these ecological and economic conditions on the adoption of PPRs have not yet been researched. Besides, these effects can mostly be explained in twofold, making it interesting to research them. Section 2.5 will discuss these conditions and its ambiguous effects in more detail.

1.2 Research objective

This research aims to determine the effects of three ecological and economic conditions on the implementation of private property rights in countries' exclusive economic zones (EEZ). These ecological and economic conditions are the exploitation status of the fish stock, the type of the fish species (being either demersal or pelagic) and the value of the fish species.

Resulting from this objective, the main research question this thesis will address is the following:

Which ecological and economic conditions affect the adoption of private property rights in fisheries management?

An answer to this research question helps to determine factors underlying the adoption of private property rights in fisheries management. These findings can help explain why some countries adopted PPRs in its fisheries, while other countries are lagging behind.

1.3 Methodology

This research will be conducted using a literature review and data analysis. The literature review will be mainly used for the chapter on the theoretical background and to formulate the hypotheses. The data analysis will be done to estimate the causal effects between (1) the exploitation status of the fish stock, (2) the type of the fish species and (3) the value of the fish species and PPR implementation. The econometric analysis will be conducted by exploiting an extensive data set on global fisheries consisting of ecological, institutional and economic characteristics (Froese & Pauly, 2019; Isaksen & Richter, 2019). In the data analysis, the dependent variable will be PPR implementation, which will be covered by two different variables. Different estimation techniques will be conducted in order to find the results on the research objective. The econometric analysis will be executed using the statistical software package STATA.

1.4 Content overview

The study is organized as follows. Chapter 2 deals with the theoretical background. The chapter starts with a section on the operation of private property rights and a discussion of two important fisheries management tools: TACs and ITQs. Then, the development of global fisheries management between 1945 and 2000, motives for the adoption of ITQs and literature on institutional change and the political economy in fisheries management will be discussed. In addition, the hypotheses for the sub research objectives will be stated here. Chapter 3 deals with the methodology and data description. Here, the empirical specifications, the explanation of the data and data descriptives will be discussed. Chapter 4 describes and discusses the results of the econometric analysis for the three types of exploitation status. Chapter 5 deals with the discussion and chapter 6 contains the conclusion.

2. Theoretical background

This chapter presents the theoretical background for this research. Section 2.1 will discuss the operation of private property rights in general and in fisheries management. Besides, two key fisheries management tools will be discussed: the total allowable catch (TAC) and individual transferable quotas (ITQs). In section 2.2, the historical overview of global fisheries management will be given. First the development of the EEZs will be explained, which is necessary in understanding countries' rights and responsibilities in fisheries management. Then, the main developments in global fisheries management between 1950 and 2000 will be treated per time period. In section 2.3, the motives of several countries to implement ITQs in one, or multiple fisheries will be discussed. In section 2.4, the concepts of institutional change and the political economy will be briefly discussed in general and in relation to fisheries management. In the last part, section 2.5, the choice for the three ecological and economic conditions will be further explained and the hypotheses will be formulated.

2.1 Fisheries management

2.1.1 Private property rights (PPRs)

Smith (1977/1776) argues that specialization in production, which he also called the division of labour, is one of the key drivers of productivity and production growth. This system of specialization and the accumulation of capital is based on the possibility of trade, which requires the existence of property rights (Arnason, 2000). Thus, property rights, especially private property rights, are seen as essential in order to increase economic efficiency (Smith, 1977/1776). Therefore, many scholars as Arnason, Gordon, Hardin and Scott have argued that the establishment of high-quality property rights will increase economic efficiency in fisheries, thereby solving the main problems of overfishing, overcapitalization and ecosystem disruption (Arnason, 2012; Gordon, 1954; Hardin, 1968; Scott, 2000).

Recently, researchers started advocating that private property rights can improve environmental goals (Costello, Gaines, & Lynham, 2008; Fujita & Bonzon, 2005). This is based on the idea that having ownership of a natural resource creates an incentive for conservation of that natural resource (Grafton et al., 2006). However, according to Gilmour, Day and Dwyer (2012) this relationship between PPRs and stewardship is based on assumptions. They state that the implementation of private property rights does not necessarily result in resource stewardship and corresponding environmental benefits (Gilmour et al., 2012).

Property rights determine the ownership and the usage of a good or a resource. The property right holder also has the power to take the yield of the property (Millerd, 2007; Scott, 2000). Property rights can be described using six characteristics: *exclusivity*, *security*, *transferability*, *divisibility*, *duration* and *flexibility* (Scott, 1989). *Exclusivity* is seen as the most important characteristic of property rights (Grafton et al., 2004). It refers to the ability of the property rights holder to use and to manage the resource (the property) without interference of others. Excludability, preventing others to access the resource, and enforceability, the ability to make people obey the exclusive right, are important features of exclusivity (Arnason, 2005). *Security*, or *quality of title*, refers to the ability of the property right holder to oppose challenges by other individuals or the government and to hold on to his property right (Arnason, 2005). *Transferability* is the ability to transfer the property right to another individual, business or government, which enables the optimal allocation of the resource. *Divisibility*, a feature of *transferability*, refers to the ability to divide the property right or to create joint ownership (Arnason, 2005; Guerin, 2003). *Duration* refers to the time period over which one owns the property right (Grafton et al., 2004). The duration ranges from 0, in which case the property right has no value, to infinite duration (Guerin, 2003). *Flexibility* is about the limitations and the responsibilities over the use of the rights which are not covered by the previous five characteristics. Regulations by the government can often limit the flexibility of the property right holder to use the resource in the desired way (Grafton et al., 2004; Guerin, 2003). When describing common-pool resources as marine fisheries, three other characteristics of flexibility are defined: an *access and enjoyment right*, a *harvesting* or *withdrawal right* and a *management right*. Most fishers possess harvesting rights, meaning that they have the right to harvest and consume fish if they meet the set conditions of the rights (Grafton et al., 2004). It is argued that individual transferable quotas (ITQs) are not full property rights as property rights on land, since fish cannot be subject to ownership (Arnason, 2012; Soliman, 2014). However, according to McCay (2000), ITQs limit access to marine resources by assigning transferable and exclusive access rights to individuals or businesses and therefore, ITQs are to a certain extent close to private property rights. For reasons of convenience, ITQs will be regarded as actual private property rights in this research from now on.

2.1.2 Total allowable catch (TAC)

The total allowable catch (TAC) is a catch limit that is put in place for a specific fish stock. The TAC determines how many tonnes of a commercial fish stocks are allowed to be caught in a fishing season or a year (OECD, 2001b). In the European Union (EU), the TACs are set by the Council of (Agriculture and) Fisheries ministers, based on the advice by independent scientific organizations as the International Council for the Exploration of the Sea (ICES) and the Scientific, Technical and Economic Committee for Fisheries (STECF). The TACs are set on the EU level and have to be shared between the members in the form of national quotas. The EU countries then have to distribute the national quota objectively among the country's fishermen and each country is responsible for the national quota not to be exceeded (European Commission, 2019a).

Most TACs are set in line with levels of maximum sustainable yield (MSY), which is a way of dealing with unsustainable fishing (Winder, 2018). The MSY is the highest possible catch that can be harvested from a fish stock, keeping the population size at the level at which growth is maximal. Another standard for sustainable fisheries management is the maximum economic yield (MEY), which maximizes fisheries profits and is lower compared to the MSY (Perman, Ma, McGilvray, & Common, 2003). Both policy makers and actors in the fishing industry favoured setting the TAC at MSY levels at first, since it seemed able to balance the need for conservation together with the wish for economic development and securing food availability. Besides, the MSY was thought to lead to rational fisheries management and thereby solving the overexploitation of fish stocks (Webster, 2015).

However, setting up a catch limit without further corresponding regulations inevitably leads to a race to fish (Morgan, 1997). An unallocated TAC system stimulates fishers to fish as much as possible before the upper limit of the TAC is reached, since the TAC does not state how much each fisher is allowed to harvest (Gordon, 1954). In this race to fish the competition among fishers is even higher than in open-access fisheries in which there are no catch limits (Morgan, 1997). Since fishers want to fish as much as possible as quickly as possible, higher investments will be made to get larger and more efficient vessels, resulting in higher overcapitalization (Gordon, 1954). Therefore, several researchers concluded that the TAC, a conservation measure intended to eliminate overexploitation of fisheries, in the end only worsened overcapitalization in the fishing sector (Clark, 2006; Gordon, 1954; Lutchman & Hoggarth, 1999; Webster, 2015). Other negative effects of the unallocated TAC and the subsequent race to fish are reduced profitability, low quality of fish products, shortened fishing seasons and the possible compromising of safety of the fishing crew (Cochrane & Garcia, 2009; Morgan, 1997).

2.1.3 Individual quotas (IQs) and individual transferable quotas (ITQs)

The effect of catch quotas as the TAC on economic efficiency is conditional on the allocation of the total catch among fishers in the fishery. Global quotas, as the quotas described before, have proven to be inefficient. To overcome this problem, quotas should be allocated to individuals (Parsons, 1993). An individual (fishing) quota (IQ or IFQ) is a right to harvest a certain amount of fish in a specific time period allocated to an individual, being a person or a company. It is often an individual share of a larger quota, as the TAC (OECD, 2003). Since IQs ensure fishermen they can harvest a certain share of the whole quota, fishing as much as possible as quickly as possible is not needed anymore. Therefore, it is argued that the allocation of quotas to individuals can eliminate race to fish (Morgan, 1997).

There were some experiments with IQs in the 1960s that successfully showed the elimination of the race to fish. Nevertheless, economists still considered this current IQ system inefficient, since the quota quantities were set by the government rather than determined in the free market, as is the case with perfect property rights. Besides, there were now many fishers with each rights to harvest a small part of the TAC, but this is not optimally efficient for the fishery as a whole (Webster, 2015). According to Petursdottir, Hannibalsson and Turner (2001), IQs are effective in preventing further increases in the fishing fleet, but they do not incentivize reduction of the current overcapacity of the fishing fleet. According to Clark (2006), additional measures as vessel buyback an decommissioning programs should be implemented on top of the IQs to effectively reduce the problems of overcapitalized fishing fleets. Without these additional measures, fishermen would not have the incentive to sell off capital and quit the fishing sector. Besides, limited entry management is required as well, since otherwise new vessels will enter the market because of the now improved conditions for fishermen. However, the limited entry regulation can also lead to capital stuffing, in which the vessels that possess individual quotas are gradually upgraded with technological instruments in order to increase fishing power (Clark, 2006).

In order to tackle the problem of overcapacity of the fishing fleet, economists tried to come up with more efficient quota systems in the 1970s (Webster, 2015). Moloney and Pearse (1979) used the idea of "fishermen catch quotas" of Christy published in 1973 to develop a systematic theory on IQs to solve the fisheries problems (Arnason, 2007). According to Moloney and Pearse (1979), commercial fisheries could be regulated by issuing transferable rights to harvest a specific quantity of a fish stock to individual fishers or fishing businesses. The transferability of the quota provides an incentive to reduce the fishing fleet by combining the quotas onto fewer vessels and dismissing the rest (Morgan, 1997). The fishers that are more efficient would be able to buy the quota from the less efficient fishers, resulting in reduced capacity and increased efficiency of the fishery as a whole (Moloney & Pearse, 1979). According to Moloney and Pearse (1979), the prices of these ITQs should be determined in open markets, as is done with perfect property rights. When all these conditions are met, this ITQ system should be superior to other alternatives aiming rationalized fisheries management (Moloney & Pearse, 1979).

2.2 Development of global fisheries management after World War II

2.2.1 Development of EEZs

According to Wilen (2000), it is convenient to take the end of World War II (WWII) as the start when discussing global fisheries policies. Till that time, there were hardly any controls in the world's fisheries, even though most high-value fisheries were outside the legal control of coastal states. There was just simply no international consensus that active management was needed for the global fisheries. Till WWII, many biologists thought that overfishing could never take place, since the fish stocks seemed healthy and the harvest levels of coastal states had historically been low. However, post-war, states as the Soviet Union, Japan and China started to develop large fishing fleets that appeared off the coasts all over the world, resulting in rising exploitation rates, evidence of declining biomass and emerging conflicts between domestic and foreign fleets (Wilen, 2000). Since food security and economic development were of great importance to nations in this post-war period, governments wanted to protect the fish stocks near their coasts from the exploitation by other countries' fleets (Webster, 2015). Many coastal countries therefore supported the idea of extending the three miles limit of the territorial seas. The United States started in 1945 with the Truman Proclamation, in which it claimed control and jurisdiction of the natural resources on the seabed and subsoil of the continental shelf (Nandan, 1987). According to Hannesson (1991), it can be worthwhile for countries to claim exclusive ownership to marine fisheries when there is increased demand for fish products. This action of the US inspired other countries and in 1947, Peru claimed rights to regulate marine resources up to 200 nautical-miles (approximately 370 kilometres) from its coast (Nandan, 1987). This development of coastal countries claiming marine resources and taking unilateral action was possible because of the absence of international agreements on the exploitation of fishery resources (Lado, 2016). In the following years, many states followed the actions of Peru and by the end of the 1970s the Exclusive Economic Zone (EEZ) was the international norm. The 200 miles-limit was internationally agreed on in the Convention on the Law of the Sea (UNCLOS) made in 1982, but the convention only came into force in 1994 (Winder, 2018). From this moment, maritime states are responsible for the optimal exploitation of the natural resources in their EEZ. This implied setting up total allowable catches for each fishery in the EEZ (United Nations Convention on the Law of the Sea, 1982). The establishment of the EEZ also enabled fishing states to assign property rights to fishers (Pauly, Watson, & Alder, 2005). To manage the shared stocks that migrate between the EEZs of two or more countries, bilateral and multilateral agreements had to be formed (Gezelius & Raakjær, 2008).

Next to the management of global fisheries in countries' EEZs, there is also the management of marine resources within the high seas, which are the waters beyond national jurisdiction (White & Costello, 2014). The high seas cover approximately 58% of the global oceans, however only 15% of the global marine catch was caught in these waters in 2003, but Pauly argues that in recent times this share has declined to less than 10% (Cullis-Suzuki & Pauly, 2010; Schiffman, 2018). On the high seas, regional fisheries management organizations (RFMOs) are responsible for fisheries resources management. However, some areas as the Arctic and the Central Atlantic are not under the management of a RFMO (European Commission, 2019b). In these excluded areas individual flag states are responsible for regulation, since all states have to take responsibility for the conservation of the living marine resources of the high seas (United Nations Convention on the Law of the Sea, 1982). Since the high seas are outside country's jurisdiction and management and no private property rights can be implemented there, these parts of the global sea are not taken into account in this research.

2.2.2 1950s & 1960s – Ineffective management measures and experiments with IFQs & IVQs

In 1956, the United Nations (UN) held its first Conference on the Law of the Sea (UNCLOS). The conference led to the conclusion of four treaties and was therefore considered successful, however, it failed to come to an agreement on two important issues: the breadth of the territorial seas and fishing limits (Bowett, 1960). Two years later in 1960, the second Conference on the Law of the Sea (UNCLOS II) was held, but again the conference did not lead to agreements on these two outstanding topics (Dean, 1960). Also, in the European Economic Community (EEC), there were no concerns about the sustainability of the fisheries at the time. Fisheries were seen as a source of food for the European citizens rather than an issue of managing exhaustible marine resources. Besides, most fish stocks were in a good state and together with the ignorance about problems of overfishing, management of marine fish resources was not seen as problematic (Lado, 2016).

However, in the 1960s, global fish harvests started to increase radically, and several countries started with (voluntary) constraints in its fisheries since biologists argued that the excess fishing mortality could lead to stock depletion. These regulations involved gear prohibitions and measures such as a minimum mesh size to prevent catching juvenile fish (Wilen, 2000).

The introduction of the unallocated TAC in the 1960s turned out to be ineffective in solving overcapitalization in the fisheries (Webster, 2015). Since the TAC increased the race to fish, the overcapitalization only got worse. Governments of fishing states implemented other management measures and started cutting the fishing effort by limiting the total number of vessels allowed and imposing taxes and fees to fishermen to increase their costs. However, enforcement of some of these measures appeared to be rather difficult, which made these restrictive measures politically attractive to fishermen (Scott, 1989). In the end, the problem of overcapitalization still prolonged and it led to experiments with IQs and ITQs in the mid-1960s (see section 2.1.2).

2.2.3. 1970s - Establishment of efficient ITQs

In the 1970s, the first ITQ systems were established in fisheries management. Iceland was the first country to adopt an ITQ system in one of its fisheries (Arnason & Runolfsson, 1997). Webster (2015) described this institutional change in Iceland as “a matter of necessity” (p. 304) rather than a decision that was based on the available economic arguments in favour of ITQ implementation. Because of overfishing and negative environmental conditions, the biomass of herring declined rapidly and the Icelandic stock almost collapsed in the 1960s (Arnason, 2005). In order to prevent the total collapse of the stock, Iceland established an unallocated TAC system in 1966. As already explained, unallocated TAC systems are not effective in solving problems in fisheries since they result in the race to fish. In Iceland, the unallocated TAC did not stop the decline of the herring stock, and fishing effort stayed high. Thus, the unallocated TAC system turned out to be ineffective. Therefore, the government introduced a moratorium on the herring fishery in 1972, meaning that it was prohibited to fish herring at all (Arnason, 2005). When the herring fishery was reopened in 1975, the fleet was too large for the relatively small TAC, so the Icelandic government introduced an IVQ system with limited entry. Since the vessel quotas were too small for fishers to survive economically, fisheries managers created an informal trading system of the IVQs. In this way, fishers could buy quotas from other fishers, making the sector more efficient. In 1979, the Icelandic government formalized this ‘managers-created’ ITQ system (Arnason, 2005). The formalized ITQ system resulted in a reduction in fishing effort and less overcapitalization in the Icelandic herring fishery (Webster, 2015). This was seen as a fisheries management success; however, the revival of the herring stocks was also heavily the result of strong recruitment of the stock in 1971. Since the ITQ system was a perceived success, ITQs were implemented in other Icelandic fisheries as well. In the Icelandic demersal fishery, which was of great economic value, an ITQ system was implemented as well because of a sudden decline in the stock size and moderately declining profits (Webster, 2015).

Mariat-Roy (2018) argues that the ITQ system in Iceland is 100% ‘homemade’, meaning that the system has been adjusted continuously over time to the needs of stakeholders and other societal actors. Arnason (1993) concluded that the successful process towards a complete ITQ system covering all fisheries in Iceland evolved “more by trial and error than by design” (p. 206).

2.2.4 1980s – Proliferation of ITQs

After Iceland had implemented ITQs in its herring fishery, several other countries including the Netherlands and New Zealand established similar quota systems in the late 1970s as well (Webster, 2015). While in the 1970s the main reason to implement ITQs were sudden drops in fish stocks, in the 1980s countries mainly chose for ITQ systems because of the presented economic arguments. At the time, many economists supported the idea of ITQs as the dominant method in managing global fisheries. Still, the development of ITQ systems was also a reaction on declining stocks, but these conditions were not as severe as the bioeconomic crises in the 1970s. Besides, fisheries managers and governments also saw the successes of ongoing ITQ experiments, so they could follow their example (Webster, 2015).

In the 1980s, the growth of the global fish catch increased again after the period of no growth in the 1970s, but it did not reach the rate of six per cent a year that was attained before the 1970s. However, this increase in global catches was mainly due to two main developments: new fishing areas were opened and new fish species were now exploited. So even though there was higher growth again in global fish catches suggesting good state of the stocks, the scarcity of fish increased certainly as well (Hannesson, 1991). At the same time, the third United Nations Conference on the Law of the Sea was concluded, establishing the 200-miles EEZs (see section 2.1.1).

In 1983, the EEC adopted its common fisheries policy (CFP), of which the conservation policy and the structural policy are the most relevant pillars for fisheries management. The conservation policy has the goal to keep the fish stock at a healthy level, using fixed TACs and technical conservation measures directed at preventing catching undeveloped juvenile fish as the main instruments (Gezelius & Raakjær, 2008). Despite the introduction of the CFP, the general feeling at the time was that there was no problematic overfishing of the European fish stocks, ignoring some fish stock collapses (Lado, 2016).

2.2.5 1990s – Wave of global collapses and alternatives to MSY approach

In the early 1990s, there was another global wave of collapses of commercial fish stocks. The collapse of the cod fisheries in the Northwest Atlantic is probably one of the most infamous collapses (Webster, 2015). This fish stock collapsed in the 1990s after years of overfishing and persisting negative environmental conditions for the stock. In 1992, a moratorium was imposed by the government, allowing for recovery of the cod stock. However, recovery did not happen and the fishery remained closed, which caused more than 30.000 people in the sector to become unemployed (Mason, 2002; Pedersen et al., 2017).

The collapses in commercial fisheries led to the emergence of new management standards for optimal fisheries management in the 1990s. Concepts like the *precautionary approach* and *ecosystem-based management* were seen as alternatives to the dismissed MSY approach (Webster, 2015). The precautionary approach in natural resource management evolved following problematic political delay concerning marine pollution in Europe (Hewison, 1996). In fisheries, conservation-oriented groups regarded the precautionary approach as the solution to the delayed decision making in fisheries management based on scientific uncertainty. In many fisheries, fishers did reject information from experts and scientists who wanted to reduce the fishing effort or catches that contradicted the catches they themselves observed (Hewison, 1996). The precautionary approach was included as the *precautionary principle*, which is codified in the Rio Declaration of 1992: “When there are threats of serious or irreversible damage, lack of scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (United Nations Conference on Environment and Development, 1992).

To summarize, regulations in fisheries management were first primarily focused on reducing conflicts among fishers and securing access to fishing grounds. When signals of overfishing and stock depletion first became apparent, these signals were ignored since the marine fish stocks were seen as inexhaustible. Conservation of marine fish resources only became a key factor in fisheries management after the collapses of several major fisheries in the second half of the 20th century. Nowadays there is a consensus among researchers that global fisheries are in crisis, however there is yet no agreement on how to proceed (Webster, 2015).

2.3 Motives for ITQ implementation

In her study on ITQ systems, Chu (2009) researched the motivations for the implementation of ITQ systems around the world. These reasons for adoption will be discussed per fishery and/or country.

In Iceland, IVQs were introduced aiming to limit the fishing fleet and to conserve the recovering herring stock (Chu, 2009). Successes in the herring fishery led to the adoption of ITQs in the other fisheries in Iceland as well (Arnason, 2005). In Canada, there are multiple fisheries in which ITQ systems were adopted. ITQs were implemented in the Scotia-Fundy ground fish fishery to combat the overcapitalization that was caused by government subsidies and high profits (Chu, 2009; Liew, 2001). In the ground fish trawl fisheries, ITQs were implemented because of concerns for exceedances of the TAC and the temporary closing of the fishery two years earlier (Chu, 2009; Sanchirico, Holland, Quigley, & Fina, 2006). In the Pacific halibut fishery, measures taken aiming to better manage the fisheries resulted in a very short fishing season of only 10 days. This resulted in dangerous working conditions for fishermen, difficulty in sticking to the TAC and reduced profitability as the supply was very high and not spread over a longer fishing season (Marsden & Sumaila, 2004). An IVQ system was implemented in this fishery aiming to combat these negative effects, in which it succeeded (Chu, 2009). Also in the US, several fisheries adopted ITQ systems. In the wreck fish fishery off the Atlantic coast, an ITQ system was developed because of rapidly increasing numbers of active fishing vessels and increasing conflicts between managers and fishers and among fishers (Chu, 2009; Gauvin, 2001). In the surf clam offshore fishery, the low biomass level led to a vessel moratorium and it reduced the allowable fishing times drastically, resulting in decreased efficiency of the surf clam offshore fishery. An ITQ system was implemented to improve the economic efficiency and resulted in less active fishing vessels (Chu, 2009; Wang, 1995). In Chile, the government proposed a law that aimed to implement an ITQ system as private fishing firms were frustrated because of the declining stocks, free access to fishing grounds, little fishing regulations and the lack of enforcement. However, this law was rejected by a significant part of the Chilean fishers and later a less strict quota system partially consisting of ITQs was implemented (Chu, 2009; Peña-Torres, 1997). In New Zealand, ITQs were implemented aiming to conserve the depleted fish stocks inshore and to improve the efficiency of the fisheries offshore to be more competitive in the international market (Chu, 2009; Newell, Sanchirico, & Kerr, 2002). In Estonia, the motives for developing an ITQ system were the problems of overfishing and overcapitalization in the fishing sector (Chu, 2009; Vetemaa, Eero, & Hannesson, 2002). In the Falkland Islands, fluctuating catches in the two most popular fish species and the losses in revenue because of marketing and international processing of the harvest led to the development of an ITQ management regime. The secured access to the stock as a result of ITQ implementation resulted in improved economic performance of the national fishing businesses (Chu, 2009; Harte & Barton, 2007).

To summarize, the main motives for ITQ implementation found by Chu (2009) are: stock depletion caused by overexploitation and overcapitalization in the fishery, political change, concerns about the viability of fishing (and thus the job security of actors involved in the fishing industry), improvement of economic performance of domestic fishers or fishing businesses or some combination of these motives (Chu, 2009).

2.4 Institutions, institutional change and responsive governance

2.4.1 Institutions and institutional change

Institutions consist of a set of rules, or humanly devised constraints, that structure social, political and economic interaction between humans. Institutions can be either formal, like laws and policies, or informal, like social norms and traditions (North, 1990). In this research the focus will be on formal institutions, from now on also called institutions.

According to North (1990), *institutional change* is essential in understanding changes in history since it influences the development of societies through time. Institutional change is typically an incremental process of small changes in existing structures (North, 1990). Webster (2009) argues that institutional change usually is a slow, adaptive process of trial and error. According to North (1990), path dependency, which is the tendency of institutions to develop in a particular way because of its structure, influences the direction of changing institutions. This is in line with the idea of Webster (2009), who argues that the potential for change is almost always limited because it is dependent on institutional precedents. Raiser et al. (2001) support this idea of path dependency, since they argue that institutions are dependent on its historical context.

Even though institutional change is often described as slow, gradual and incremental, institutional changes can also be abrupt and radical (Young, 2010). According to Webster (2015), rapid change is also possible in institutions in fisheries management, but only in cases of a sudden collapse of a resource stock or political regime.

2.4.2 Political economy

The concept *political economy* can be used to describe the interaction between the government, citizens and stakeholder groups (OECD, 2011). Governments, consisting of both elected representatives of the public and civil servants, can be motivated in making policy decisions by ideological beliefs, obtaining maximum social welfare, achieving economy efficiency or the aspiration to retain office. Decision makers aim to maximize their objectives, which can be both egoistic and altruistic, and these objectives will be reflected in the government policy decisions. Citizens and stakeholder groups can reveal their opinion or preferences concerning policies through voting or lobbying or other channels (OECD, 2011).

Decision makers are often hesitant concerning institutional change, since it is often costly and risky (Neher, Arnason, & Mollett, 1989). Especially when a policy reform will be costly in advance, while it may take some time before the benefits will be presented, people with the right to vote are able to 'punish' the current decision makers for their political decisions. Therefore, the public opinion matters to decision makers (OECD, 2011). In most countries, people are strongly opposed to major changes in the institutions concerning production and employment. This opposition is often the result of traditional values and private interests in the sector rather than rationality (Arnason, 1993).

2.4.3 The political economy of institutional change in fisheries

According to Quaas, Stoeven, Klauer, Petersen, & Schiller (2018), the implementation of sustainable management measures in fisheries is in the public interest. However, this interest is intertwined with the private interests of different stakeholders active in the fishing industry. Historically, in many fisheries the implementation of the optimal solution did not take place or was delayed, because it would harm the interests of influential groups in the fishing industry. This pattern of ineffective management led to the worsening of environmental problems in the fisheries sector (Quaas et al., 2018). This is an example of *responsive governance*: decision makers are always catching up with environmental problems or crises rather than taking actions to prevent them (Webster, 2015). Decision makers first come up with simple and less effective measures and they are only willing to try the more costly but effective measures if the problems continue or get worse (Webster, 2009). According to Arnason (1993), this process of trial and error is unavoidable because of the strong social opposition to fundamental changes in institutions, especially concerning employment.

To summarize, decision makers in fisheries management are often reluctant to take unpopular decisions concerning the implementation of policy reforms, or their response is insufficient. Only when decision makers were forced to respond to severe signals of overuse such as stock depletion, management actions were taken as emergency measure to rescue a fishery (Webster, 2015; Isaksen and Richter, 2019). This corresponds to the findings of Neher et al. (1989), who argue that even though there are economic arguments, history shows that a crisis or an exogenous shock is crucial in order to urge decision makers into institutional change. According to Arnason (1993), fishers and other involved stakeholders in the fishing industry are reluctant to accept changes in the established organization of the fisheries and the lack of made decisions shows that decision makers takes their opinions into account when making policy decisions. History showed that fishermen were only willing to think about changes in the traditional organization of the fisheries when they were confronted with a crisis that affected them personally, as a significant income reduction due to sudden declines in fish stocks (Arnason, 1993).

2.5 Variables of interest and hypotheses

In the next part of this research, the focus will be on the effect of the three ecological and economic conditions, e.g. the exploitation status of the fish stock, the type of the fish species and the value of the fish species, on the implementation of PPRs in fisheries management. In this section, the selection of these specific conditions will be justified and explained. Each section will end with a hypothesis.

2.5.1 The exploitation status of the stock

The literature showed that decisions about institutional change are often only made when there is a crisis such as a severe stock depletion, as a final measure to rescue the fishery (Arnason, 1993; Isaksen and Richter, 2019; Neher et al., 1989; Webster, 2015). Therefore, it will be interesting to research the effect of the exploitation status of the stock, which varies from *undeveloped* and *developing* to *fully exploited*, *overfished*, *recovering* and *collapsed*, on the probability of PPR implementation. The literature on institutional change implies that fish stocks that are in a bad shape and are close to collapse will be more likely to undergo PPR implementation. However, it is also argued that fish stocks that are in bad shape are less likely to undergo PPR implementation. This reasoning has to do with the economic reasons for implementing PPRs: When there is a lot of profit to be gained in a fishery, then it is worthwhile to implement PPRs since it will protect the profit. When a fish stock is close to collapse, the profitability will be lower, resulting in PPR implementation not being that worthwhile (Isaksen & Richter, 2019). Thus, the effect of the exploitation status of the stock can be a bit ambiguous. However, here the first argument, that a crisis will be the cause for institutional change, will be followed. Therefore, it is hypothesized that: *A fish stock being close to stock depletion increases the probability of PPRs being implemented in the fishery*.

2.5.2 The type of the fish species

Fisheries can be divided in two main groups: demersal and pelagic fisheries. Demersal fish live on or close to the bottom of the sea, while pelagic fish occupy the surface and subsurface waters. Demersal fish are mainly used for human consumption and are of higher value compared to pelagic fish species (Khedkar, Jadhao, Chavan, & Khedkar, 2003).

According to Lutchman & Hoggarth (1999), ITQs favour the large, highly efficient, capital-intensive businesses over small-scale fishers. ITQ implementation is likely to result in the accumulation of quotas among the capital-intensive businesses and the collapse of traditional fishing communities, thereby negatively affecting employment levels (Lutchman & Hoggarth, 1999). In some cases employment also increased after the fishery had been privatised, however in most cases PPR implementation led to a decline in employment (Olson, 2011; Quaas et al., 2018).

According to the literature on the political economy, decision maker often take the preferences of citizens into account since decision makers can be 'punished' for their political decisions by the voting behaviour of citizens (OECD, 2011). Most citizens are opposed changes that affect the level of employment in a sector or country (Agnarsson, 2009), and therefore it is likely that decision makers will make policy decisions that do not harm the current employment level. Since ITQ implementation can negatively affect the employment level in the sector, policymakers will not implement PPRs in fishing sectors in which employment is high. Unfortunately, there are no clear statistics on the employment level in demersal fisheries and pelagic fisheries. However, based on the higher commercial value of demersal fish, the higher search costs for pelagic fish and the high sensitivity to environmental changes of pelagic fish, it is assumed that employment is higher in demersal fisheries compared to pelagic fisheries (Khedkar et al., 2003; Shannon, Jarre, & Schwing, 2009). Based on this assumption and the previous line of reasoning, it can be argued that PPRs will be implemented more often in pelagic fisheries because of the potential negative effect when implementing PPRs in demersal fisheries. On the other hand, Isaksen and Richter (2019) state that migratory species, as pelagic fish, are less likely to be managed by a quota system. So, there is quite some ambiguity on the likelihood of PPR implementation in demersal and pelagic fisheries. However, based on the uncertain character of the first argument, the second argument is followed. Therefore, it is hypothesized that: *A fish species being demersal increases the probability of PPRs being implemented*.

2.5.3 The value of the fish species

The third variable of interest is the value of the fish species. According to Isaksen and Richter (2019), the value of a natural resource as marine fisheries may influence adoption of PPRs. Again, the effect of this variable can be either positive or negative. On the one hand, there is a stronger economic incentive to implement PPRs for fish species with a higher value, since there is more to be gained (Isaksen & Richter, 2019). On the other hand, high value species could be under larger pressure, which might require higher efforts in monitoring and enforcement, making it less attractive to implement PPRs (Isaksen & Richter, 2019; Kaffine, 2009). However, here the first argument will be followed, resulting in the following hypothesis: *An increase in the price of fish species will have a positive effect on the probability of PPRs being implemented in the fishery.*

3. Methodology and data description

This chapter deals with the methodology of this research. In section 3.1, the origin of the used data set and the variables of interest will be discussed. In section 3.2, the descriptive statistics will be treated and analysed. Section 3.3 will discuss the empirical models that are used for the estimations.

3.1 Data and constructed variables

The data set used in the empirical analysis is an aggregation of data used in the paper of Isaksen & Richter (2019) and ecological data from Fishbase (Froese & Pauly, 2019). The former data set consists of ecological data from the Sea Around Us (SAU) global catch database, biomass data from the RAMLegacy Stock Assessment Database, information on quota systems from the Environmental Defense Fund (EDF) catch share database, species specific growth parameters from FishBase, data on the Rule of Law indicator from the World Bank's Worldwide Governance Indicators and country characteristics as gross domestic product (GDP) per capita and population growth from OECD statistics (Isaksen & Richter, 2019). Fishbase is an online database with key information on over 30.000 fish species over the world. Published data from researchers is evaluated on a set of quality and validity criteria by a team of expert encoders of FishBase (Christensen & Maclean, 2011). The data set used in this research concerns panel data consisting of 162,947 observations over the time span 1950-2006. The units of observation are unique combinations of fish species in a specific EEZ and year. The data set consists of 6337 fisheries (species-EEZ combinations), however not all fisheries have observations for all years of the time period, so the data is unbalanced. On average, each fishery contains 26 observations.

This research aims to determine the effect of three ecological and economic conditions on the adoption of PPRs in fisheries management. The outcome variable of interest will be PPR implementation. PPRs are defined as any quota system that has tradable or non-tradable property rights. This is in line with the specification used in Isaksen and Richter (2019), in which the causal effect of PPRs on the overexploitation of fisheries is investigated. The variable PPRs includes different types of quota systems as IQs, ITQs, IVQs and TURFs. Even though there are notable differences between these types of quota systems, the quota systems are not distinguished from each other. The focus of this research is on the general character of (private) property rights rather than on the specific details and differences between the different types. The first outcome variable, dummy variable *ppr_implemented_cc*, captures the difference between PPRs and no PPRs and thus takes the value of 1 for all the years in which PPRs are present. The second outcome variable, dummy variable *transition_into_PPRs*, captures the actual transition into PPRs and thus only takes the value of 1 for the year in which PPRs were implemented.

The exploitation status of the stock is an ordinal, constructed variable with six categories*: undeveloped*, *developing*, *fully exploited*, *overfished*, *recovering* and *collapsed*. Catch data is used to derive the exploitation status for each species. The different stages of exploitation status and the criteria used to determine the exploitation status originate from Froese, Zeller, Kleisner & Pauly (2012). This determination of the different types of exploitation status is based on the assumption that catch reflects biomass. In cases of changing consumer preferences or natural fluctuations in fish stocks, catch does not reflect abundance of fish and the assumption is not met (Isaksen & Richter, 2019). However, even though this assumption of catch reflecting biomass can be a bit problematic, it is argued that it is the best way to research exploitation status on a global scale. Aggregating data for the estimation of biomass of fish species is costly and for that reason biomass data is often only available for commercial fish stocks that are caught by developed countries, which would result in a biased subsample (Isaksen &

Richter, 2019). In order to determine the effect of the different categories of the exploitation status, dummy variables for each category are made.

The type of the fish species is represented in the data set by seven different categories including for example *benthopelagic*, *pelagic-neritic* and *reef-associated*. However, the distinction between these specific categories of demersal or pelagic fish species is not of interest in this research, so therefore all categories are merged into two overarching dummy variables: *GROUPdemersal* and *GROUPpelagic*.

To capture the value of fish species, a variable indicating the price of the fish species will be used. This price is a single world price in US$ per tonne of caught fish that is the average from each species across all countries. This means that the price of for example Dutch whiting *(merlangius merlangus)* in 1969 is equal to the price of Bulgarian whiting in 1969. This real world price per taxon, from now on just called *price*, will be used in order to overcome potential problems of endogenous local prices (Isaksen & Richter, 2019). Another variable used to indicate the value of the fish species is the price category variable, which contains four different price categories: *low*, *medium*, *high* and *very high*. Dummy variables for each category were made to be able to determine the effect of the different price categories.

The data set also includes some data on country characteristics that will be used as control variables in the analysis. These variables are population growth (in %), GDP per capita (in constant 2005 US$), economic openness (in %, measured by import plus export, divided by GDP), polity index (from -10 (autocracy) to 10 (democracy)), and the number of ratified international environmental agreements as a proxy for a country's environmental awareness. Unlike the variables so far, the data on country characteristics is only available at the country level. In the analysis, the natural logarithm of GDP per capita is used in order to get a normal distribution. This means that the values of the GDP per capita stated in the data description (section 3.2) represent the logarithm of the GDP per capita and not the actual GDP per capita. Another control variable, available on the EEZ level, is the leave-out mean collapse rate. This collapse rate is a constructed variable that represents the collapse rate for the EEZ, without including the specific fishery. By including this (leave-out) mean collapse rate, common trends to the whole EEZ, such as a temperature shock, are controlled for (Isaksen & Richter, 2019).

Besides, dummy variables were created for the eight different regions in the world. The different regions in the data set are: *Africa, the Caribbean, Eastern Europe and Central Asia, Latin America, the middle East, Oceania and the Pacific, South and East Asia* and *Western Europe and North America*. These region dummies will be used in the data description to look at the geographical differences for PPR implementation and the other variables. Lastly, dummy variables were created for the different categories of (commercial) importance of the fishery. The dummy variables include: *commercial, highly commercial, of no interest, minor commercial* and *subsistence fisheries*. However, it is unclear on the basis of which characteristics this classification of (commercial) importance came about. Still, the original data has been assessed by the Fishbase expert team and therefore it is assumed that the classification of the variable is reliable. This variable is the best one available to use in the data description to look at the differences in PPR implementation and the other variables for fisheries with different commercial importance.

3.2 Data descriptives

In this section, the descriptive statistics will be analysed. The data set consists of 6337 distinct fisheries, which are combinations of a fish species in a specific EEZ. In 2.95% (187 out of 6337) of the fisheries in the sample, PPRs were implemented in a given year between 1950 and 2006. First, the analysis will mainly take place on the observations level, to compare the values of the control variables of different groups: *PPR* vs. *Non-PPR* and *demersal* vs. *pelagic*. Then, the analysis will mainly take place on the fishery level, because of the panel data character of the data.

Table 1 shows the summary statistics on the observations level for the price variable and the control variables grouped by PPR implementation: *Non-PPR* includes the observations of the fisheries in which no PPRs have been implemented, while *PPR* includes all the observations belonging to the fisheries in which PPRs were implemented during the time span. What stands out is the unequal distribution in number of observations between the two groups (160,269 for Non-PPR vs. 2678 for PPR), which can be explained by the fact that in only 1.64% of all observations PPRs are present. The table shows that the mean value of the price variable is higher for non-PPR fish species (2412.407) compared to PPR fish species (2061.884). The trade openness is also higher for non-PPR (64.481) compared to PPR (59.108). However, the mean values for GDP per capita, the polity score and the amount of ratified international environmental agreements are higher for PPR species, while population growth is lower (even negative) for PPR species.

Table 1. Summary statistics by PPR implementation

	Non-PPR			*PPR*		
Variable	count	mean	sd	count	mean	sd
Species-level data:						
World price (US$ per tonne)	160269	2412.407	2482.714	2678	2061.884	2187.914
EEZ-level data:						
(leave-out) Mean collapse rate (0,1)	160181	0.144	0.153	2678	0.226	0.126
Country-level data:						
GDP/ capita, log	112108	8.582	1.606	2628	10.215	0.609
Population growth, %	132195	0.174	0.985	2517	-0.215	0.651
Trade openness, %	111830	64.481	41.482	2623	59.108	26.550
Polity (-10,10)	120193	3.459	7.442	2666	9.826	0.822
environmental agreements, log	150296	2.554	1.260	2678	3.665	0.691

Table 2 shows the summary statistics grouped by the type of the fishery, being either demersal or pelagic. Out of the 187 fisheries in which PPRs have been implemented, 130 are demersal fish species (69.52%), and 57 are pelagic fisheries (30.48%). The table shows a small inequality in the number of observations, 73495 demersal observations vs. 89452 pelagic observations. The mean value of the price variable is higher for demersal fish species (2541.835) in comparison to pelagic fish species (2295.573). The mean values of country-level data as GDP per capita, polity score and the number of ratified international environmental agreements are higher for demersal fisheries, while trade openness is higher for pelagic fisheries.

Table 2. Summary statistics by the type of the fish species

	Demersal			*Pelagic*		
Variables	count	mean	sd	count	mean	sd
Species-level data:						
World price (US$ per tonne)	73495	2541.835	2960.877	89452	2295.573	1990.059
EEZ-level data:						
(leave-out) Mean collapse rate (0,1)	73494	0.154	0.135	89365	0.139	0.166
Country-level data:						
GDP/ capita, log	54425	9.058	1.526	60311	8.223	1.579

Population growth, %	60133	-0.086	0.990	74579	0.371	0.925
Trade openness, %	54690	62.101	35.932	59763	66.423	45.405
Polity (-10,10)	60090	4.981	7.085	62769	2.273	7.492
environmental agreements, log	71311	2.848	1.179	81663	2.334	1.280

Table 3 shows the PPR implementation in fisheries for the eight global regions. The table shows that in no single fishery from Caribbean and the Middle East in the data set, PPRs were implemented. The implementation of PPRs in fisheries is highest in Oceania and the Pacific (9.46%), followed by Western Europe and North America (6.17%). The degree of PPR implementation in fisheries in the four other regions (Africa, Eastern Europe and Central Asia, Latin America and South and East Asia) are all in the range 0-2.2%. Appendix A.1 includes eight tables consisting of the summary statistics for the global regions. Table A.1 till A.8 show that Oceania and the Pacific has the highest mean value for the price of fish species (3212.702) followed by Africa (2477.763) and Western Europe and Northern America (2376.096).[1] These summary statistics show that Oceania and the Pacific, the region with the highest implementation of PPRs in its fisheries also has the highest prices for its fish species.

Table 3. Summary statistics by the type of the fish species

Regions	*# fisheries*	*# transitions into PPRs*	*PPR implementation in fisheries (%)*
Africa	1401	7	0.50
Caribbean	472	0	0
Eastern Europe and Central Asia	496	5	1.01
Latin America	510	11	2.16
Middle East	477	0	0
Oceania and the Pacific	444	42	9.46
South and East Asia	623	4	0.64
Western Europe and North America	1914	118	6.17
Total	6337	187	2.95

Table 4 shows the implementation of PPRs in fisheries for the different categories of the variable (commercial) importance[2]. The table shows that in the categories ‘subsistence fisheries’ and ‘of no interest’ no PPRs have been implemented in a single fishery. Subsistence fishing is often small-scale, in which artisanal, low technological fishing techniques are used, primarily for personal consumption or to feed family and relatives (OECD, 2001a). The implementation of PPRs in fisheries is highest in the *highly commercial* fisheries (5.02%), followed by the category *commercial* (2.29%) and *minor commercial* fisheries (1.02%). These outcomes are in line with the economic reasoning for implementing PPRs mentioned in section 2.5.1, that PPRs will protect the profits that can be gained in a fishery (Isaksen & Richter, 2019). In subsistence fisheries, in which there is no commercial aspect, PPRs are thus not needed, while PPR implementation will be higher in (highly) commercial fisheries. Appendix A.2 includes six tables consisting of the summary statistics for all categories of (commercial) importance. The mean of the price variable is highest for commercial fisheries (2631.627) and lowest for the category *of no interest* (1422.353).

[1] The Caribbean and the Middle East are excluded here, since PPR implementation is 0 in these regions.

[2] The category *NA*, which stands for *not available*, is excluded from the analysis, since this category has no economic meaning. For the sake of completeness of the overview of the numbers, the category is nevertheless included.

Table 4. PPR implementation in fisheries by (commercial) importance

(commercial) Importance	*# fisheries*	*# transitions into PPRs*	*PPR implementation in fisheries*
Commercial fisheries	2885	66	2.29%
Highly commercial fisheries	2151	108	5.02%
Minor commercial fisheries	1174	12	1.02%
Of no interest	26	0	0.00%
Subsistence fisheries	63	0	0.00%
NA	38	1	2.63%
Total	6,337	187	2.95%

Figure 1 gives a graphical overview of the fisheries in which PPRs are implemented by four categorical variables: *exploitation status*, *price categories*, *regions* and (*commercial) importance*. According to the figure, fisheries in which PPRs have been implemented are often fully exploited, have a low price, are highly commercial and are located in Western Europe and North America.

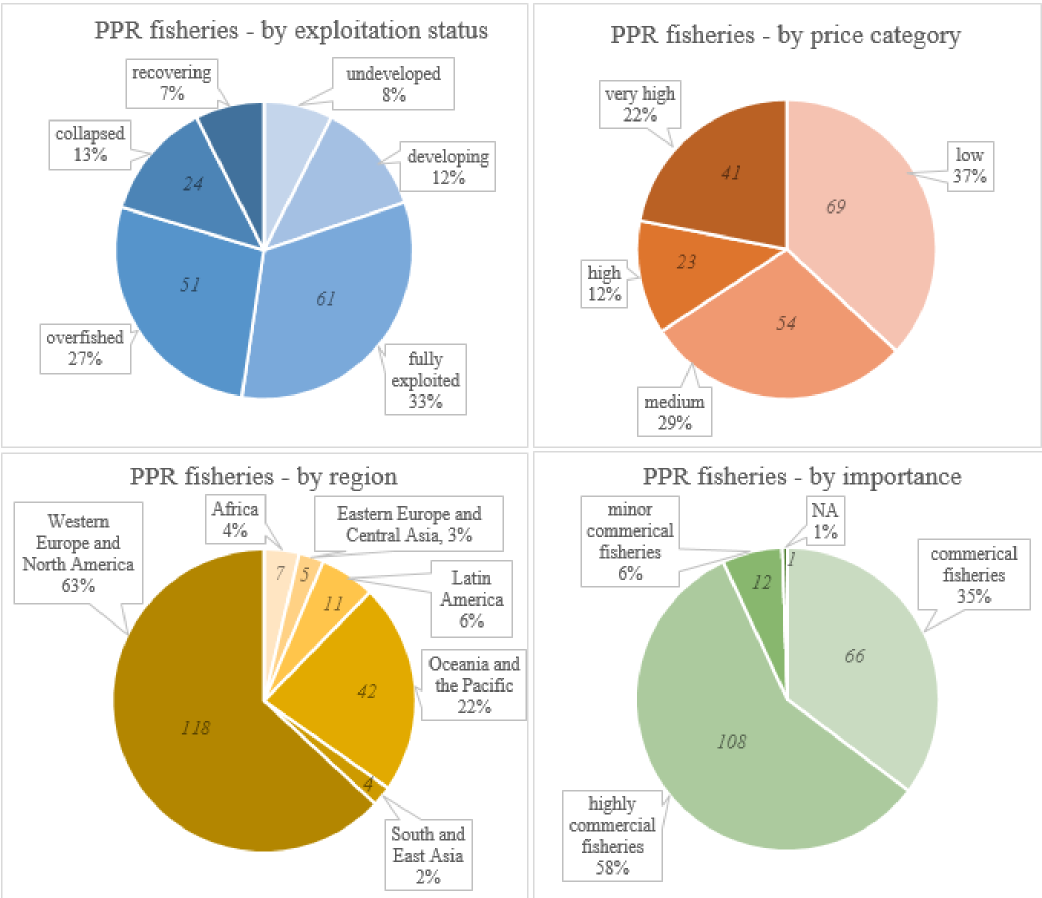

Figure 1. Graphical overview of the 187 fisheries that have implemented PPRs

The numbers in the pie chart are the absolute numbers of PPR fisheries in that category. The numbers for the exploitation statuses 'recovering', 'undeveloped' and 'developing' are omitted since these categories are excluded from the analysis.

3.3 Empirical specification

The research objective in the data analysis is to determine the effects between (1) the exploitation status of the fish stock, (2) the type of the fish species and (3) the value of the fish species, and PPR implementation in fisheries management. One of the key aspects of establishing causal effects is the notion of ceteris paribus, e.g. holding all other, relevant, factors fixed. Using econometric models, the other relevant factors can be hold fixed and the effect of the three variables of interest on PPR implementation will be conditional on the set of the control variables. Establishing causality is key, because without it, it cannot be concluded that the three variables on its own have any effect on PPR implementation (Wooldridge, 2010).

In all regressions, the dependent variable will be the implementation of PPRs. In the main analysis, the outcome variable will be *ppr_implemented_cc*. This dummy variable takes the value of 1 if PPRs are present for the fishery in that year and the value of 0 if no PPRs have been implemented at that time. This means that this variable does not represent the 'actual' implementation of PPRs, but focusses more on the difference between years in which no PPRs were implemented versus the years in which PPRs have been implemented within a fishery. Regressions with *ppr_implemented_cc* as dependent variable will be analysed as the effects of the three ecological and economic variables on the probability of PPRs being implemented. Another dummy variable, which is named *transition_into_PPRs*, captures the year of implementation of the PPRs. If PPRs were implemented in 1990, *transition_into_PPRs* will only take the value of 1 for this fish stock in 1990, while *ppr_implemented_cc* takes the value of 1 for 1990 and all subsequent years until and including the last observed year in the data set. Regressions with *transition_into_PPRs* as dependent variable will be analysed as the effects of the three variables of interest on the probability of PPR implementation. Because of the strict specification of the variable *transition_into_PPRs,* the number of actual PPR implementations in the data set is very small, while the number of years in which PPRs have been implemented (*ppr_implemented_cc)* is almost 15 times as big. Even though the variable *ppr_implemented_cc* does not capture the actual implementation of PPRs, this variable will be used in the main analysis since it is very useful as an instrument in providing the 'overall picture' of determining which ecological and economic conditions affect the adoption of PPRs. All regressions from the main analysis will also be done with *transition_into_PPRs* as a dependent variable in section 4.4 as a robustness check.

With *ppr_implemented_cc* as dependent variable, it is likely that there will be positive autocorrelation or 'persistence', which is the tendency for a system to stay in the same state from one to the next observation (Wooldridge, 2010). When the outcome is '1' at time *t* (and PPRs are thus implemented), at time *t+1* and *t+2* and so on, the outcome will be '1' as well. However, autocorrelation, which is the correlation of the error terms and can cause problems in conventional analyses that assume independence of observations, is often not considered a major issue in panel data models when the number of observations (N) in the data set is sufficiently large. In order to deal with the possibility of autocorrelation, the error terms will be clustered (Wooldridge, 2010). With *transition_into_PPRs* as dependent variable, positive correlation or persistence will not be an issue, since there will only be one observation that has the outcome '1'.

In this research the STATA estimation command *reghdfe* is used to estimate the econometric models. This relatively new command has become the default tool for estimating linear models with multiple high-dimensional fixed effects (HDFE) (Correia, Guimarães, & Zylkin, 2019), but it can also be used for non-linear and other types of regressions (Correia, 2017). In Isaksen & Richter (2019), the *reghdfe* command was used to estimate a model with a binary outcome, as will done in this research. Besides, with the ability of including more than one level of fixed effects, the *reghdfe* command is also more feasible in the estimation of large data sets compared to the conventional estimation commands as *areg* or *xtreg* (Correia et al., 2019). The choice for a fixed effect model was justified by the outcome of the Hausman test (see Appendix B). The null hypothesis that the difference in coefficients between the fixed effects model and the random effects model is not systematic is rejected, concluding that the unique errors are correlated with the regressors. Therefore, a fixed effect model is preferred over the random effects model.

In the estimation, multiple levels of fixed effects will be included. Including fixed effects controls for the time-invariant unobservable variables, often interpreted as unit-specific constants (Wooldridge, 2010). Failing to control for the unobserved heterogeneity can impede establishing causality because of the omitted variable bias (Correia, 2017; Gormley & Matsa, 2014). In this research, it will be very likely that there are some characteristics of countries and/or species-specific traits that will have an impact on the implementation of PPRs and will correlate with the explanatory variables. The fixed effect estimation uses *within transformation* to remove all these unit-specific constants, thereby eliminating this correlation (Wooldridge, 2010).

In all models, a term t is included to determine the presence of a time trend. A time trend allows to control for an increase in the dependent variable, implementation of PPRs, that is not explained by the other variables in the regression (Wooldridge, 2010).

Since the data concerns panel data, the standard errors should be clustered. This will be done at the fishery level, e.g. the combination of species and EEZ (*id_eez_tax*), to account for potential serial-correlation and within-fishery correlation. Clustering of the standard errors results in the consistent estimation of standard errors even when the observations are correlated within the fishery. Failing to cluster the standard errors might lead to misleadingly small standard errors for the estimates (Wooldridge, 2010).

In the following sections, it will be explained how the empirical models used to estimate the effects of (1) the exploitation status of the fish stock, (2) the type of the fish species and (3) the value of the species, on the implementation of PPRs look like.

3.3.1 Exploitation status of the stock

The effect of the status of the stock on PPR implementation will be researched by estimating a model including multiple fixed effects. In this model, fixed effects at the species level and the country level will be taken into account. By doing so, this model can be used to look at the variation over time within a fish species in an EEZ. In this way it is possible to determine whether, for example, the exploitation status of sole in the sole fishery in France can explain the implementation of PPRs in this particular fishery.

The variable *exploitation status* contains six different categories, however not all categories are covered in the analysis. The categories f*ully exploited*, *overfished* and *collapsed* are of main interest, since these categories are closest to a crisis as severe stock depletion, which is hypothesized to be a cause for institutional change. The exploitation status *recovering* is already beyond the phase in which action can be taken, so therefore it is excluded from the analysis. The categories *undeveloped* and *developing* are also excluded, since the catch in these fisheries is relatively far from the maximum catch. This makes the exploitation status categories *undeveloped* and *developing* difficult to compare with a crisis as severe stock depletion.

Since institutional change at time *t* often is based on conditions and variables from previous years because of responsive governance, lagged values should be included as well. Five lagged values of the exploitation status, from time *t* to *t-5*, will be included. It is assumed that the exploitation status that go back further in time, for example at *t-10*, do not impact PPR implementation at time *t* anymore.

The group of control variables consist of GDP per capita, population growth, economic openness, the polity index, the number of ratified international environmental agreements and the (leave-out) mean collapse rate. The price of fish species will also be included in the model.

The model takes the following form:

$$PPRimpl_{i.j,t} = \beta_1\, EXPL_{i,j,t} + \beta_2\, EXPL_{i,j,t-1} + \beta_3\, EXPL_{i,j,t-2} + \beta_4\, EXPL_{i,j,t-3} + \beta_5\, EXPL_{i,j,t-4} + \beta_6\, EXPL_{i,j,t-5} + \gamma X'_{j,t} + \theta price_{i,t} + \lambda T_t + \alpha_{i,j} + u_{i,j,t} \qquad (1)$$

with $u_{i,j,t} \sim IID\ (0, \sigma_u^2)$,

where subscript *i* indicates species, *j* indicated country and *t* indicates year. In addition, $X'_{j,t}$ includes the time-variant control variables at the country level[3], $price_{i,t}$ indicates the single world price of species, T_t indicates the time trend, $\alpha_{i,j}$ indicates the unit-specific fixed effects and $u_{i,j,t}$ is the idiosyncratic error term. The variable of interest, $EXPL_{i,j,t}$ thus consists of three categories of exploitation status: *fully exploited*, *overfished* and *collapsed*.

This model will also be estimated with *transition_into_PPRs* as dependent variable. This model looks exactly like equation (1), but then with *transition_into_PPRs* as dependent variable instead of *ppr_implemented_cc*.

3.3.2 Type of the fish species

The effect of the type of the fish species on PPR implementation will be researched by estimating a model including fixed effects. The variable of interest, the type of the fish species, is either pelagic or demersal and does not change over time. Therefore, the fixed effects will be only at the country level, and not also on the species level as with the analysis of the exploitation status of the stock. This means that only countries which both have demersal and pelagic fish stocks will be taken into account in this analysis. The dummy variables that are used to express type of the fish species are *GROUPdemersal* and *GROUPpelagic*. The model also includes an interaction term between the three categories of exploitation status and the type of the fish species, here *GROUPdemersal*. This interaction term allows to test whether the effect of the exploitation status of the stock on PPR implementation is different for demersal compared to pelagic fish species.

The control variables consist of GDP per capita, population growth, economic openness, the polity index, the number of ratified international environmental agreements and the (leave-out) mean collapse rate. The price of fish species will also be included in the model.

The model takes the following form:

$$PPRimpl_{i.j,t} = \beta_1\, demersal_i + \zeta\, EXPL_{i,j,t} * demersal_i + \gamma X'_{j,t} + \theta price_{i,t} + \lambda T_t + \alpha_j + u_{i,j,t} \qquad (2)$$

[3] The leave-out mean collapse is constructed on the EEZ-level, but in most cases, countries and EEZs can be used interchangeably (exceptions are different islands that together form one country, but each have a separate EEZ) (Isaksen & Richter, 2019). Therefore, this variable is added to the list with control variables that contain country characteristics.

with $u_{i,j,t} \sim IID\ (0, \sigma_u^2)$,

where subscript *i* indicates species, *j* indicates country and *t* indicates year. In addition, $X'_{j,t}$ includes the time-variant control variables at the country level, $EXPL_{i,j,t}$ consists of the three categories of exploitation status, $price_{i,t}$ indicates the single world price of species, T_t indicates the time trend, α_j indicates the unit-specific fixed effects and $u_{i,j,t}$ is the idiosyncratic error term. The variable of interest, $demersal_i$, is the dummy variable that takes the value of 1 if the fish species is demersal and 0 if the species is pelagic.

This model will also be estimated with *transition_into_PPRs* as dependent variable. This model looks exactly like equation (2), but then with *transition_into_PPRs* as dependent variable instead of *ppr_implemented_cc*.

3.3.3 Value of the fish species

The effect of the value of the fish species on PPR implementation will be researched by a fixed effects model including multiple fixed effects. In this analysis, fixed effects at the species level and the country level will be taken into account. The price variable that will be included is the single world price for each species. Since institutional change at time *t* often is based on conditions and variables from previous years because of responsive governance, lagged values should be included as well. Since it is assumed that prices fish species at time *t-10* does not impact PPR implementation at time *t* anymore, five lagged values of the price will be included.

Beside the price variable on its own, the model also includes two interaction variables concerning the value of the fish. The first one is an interaction term between the price and the three different categories of exploitation status. The second one is an interaction term between the three categories of exploitation status and the four price categories: *low, medium, high* and *very high*. These interaction terms allow to test whether the effect of the exploitation status of the stock on PPR implementation is different for fish stocks that have a low, medium, high or very high price.

The model takes the following form:

$$\mathrm{PPRimpl}_{i,j,t} = \theta_1\,\mathrm{price}_{i,t} + \theta_2\,\mathrm{price}_{i,t-1} + \theta_3\,\mathrm{price}_{i,t-2} + \theta_4\,\mathrm{price}_{i,t-3} + \theta_5\,\mathrm{price}_{i,t-4} \quad (3)$$
$$+ \theta_5\,\mathrm{price}_{i,t-4}\ \ \theta_6\,\mathrm{price}_{i,t-5} + \beta\,\mathrm{price}_{i,t} * \mathrm{EXPL}_{i,j,t} + \kappa\,\mathrm{pricecat}_{i,t} * \mathrm{EXPL}_{i,j,t} + \gamma \mathrm{X'}_{j,t} +$$
$$+ \lambda \mathrm{T}_t + \alpha_{i,j} + u_{i,j,t}$$

with $u_{i,j,t} \sim IID\ (0, \sigma_u^2)$,

where subscript *i* indicates species, *j* indicated country and *t* indicates year. In addition, $X'_{j,t}$ includes the time-variant control variables at the country level, $EXPL_{i,j,t}$ consists of the three categories of exploitation status, $price_{i,t}$ indicates the single world price of species, $pricecat_{i,t}$ consists of the four different price categories, T_t indicates the time trend, $\alpha_{i,j}$ indicates the unit-specific fixed effects and $u_{i,j,t}$ is the idiosyncratic error term.

This model will also be estimated with *transition_into_PPRs* as dependent variable. This model looks exactly like equation (3), but then with *transition_into_PPRs* as dependent variable instead of *ppr_implemented_cc*.

4. Empirical results

This chapter reports on the estimated effects of the three ecological and economic conditions on PPR implementation. The results will be presented per category of the exploitation status. Section 4.1 will be about the effect of the exploitation status *fully exploited* on PPR implementation. Then the effects of the two other variables, the type of the fish species and the value of the species, and its interactions with the exploitation status *fully exploited* will be discussed. Section 4.2 and 4.3 will have the same structure, but then concerning overfished and collapsed fish stocks, respectively. In each table, column 1 accounts for the exploitation status and its lagged values, column 2 accounts for the type of the fish species and its interaction with the exploitation status and column 3 accounts for the price variables and interactions between price variables and the exploitation status.

4.1 Fully exploited fish stocks

Table 5 presents the results from the three specifications for fish species that fall under the exploitation status 'fully exploited'. The dummy variable *fully exploited*$_t$ is only significant if accounted for the price interactions. Fish stocks being fully exploited then increases the probability of PPRs being implemented by 3.12 percentage points (pp). If accounted for the lagged values of *fully exploited*$_t$, the table shows that *fully exploited*$_{t-4}$ and *fully exploited*$_{t-5}$ both have a small, positive effect on the probability of PPRs being implemented, but only at the 10% significance level (col. 1). This means that a fish stock being fully exploited four or five years before time *t*, increases the probability of PPRs being implemented at time *t* by 0.18 or 0.36 percentage points, respectively. All control variables, except for GDP per capita and the number of ratified international environmental agreements are significant at the 5% significance level, some even at the 1% significance level. The variable for the time trend is also significant and positive in all three specifications. This means that an increase in time by one year, will increase the probability of PPRs being implemented by 0.25-0.29 percentage points, depending on the specifications. This positive time trend is in line with the reality, since there were more fisheries in which PPRs were adopted in 2006 compared to, for example, 1990.

If accounted for the type of the fishery and its interaction with *fully exploited*$_t$, the dummy variable *demersal* is significant and has a positive value (col. 2). A fish species being demersal increases the probability of PPRs being implemented by 0.96 percentage points. This inevitably also means that a fish species being pelagic decreases the probability of PPRs being implemented by 0.96 pp. The interaction term between *fully exploited*$_t$ and the type of fish species[4], which corresponds to the demersal fish species in fully exploited fish stocks, is also positive, but not significant. This means that if a fish species is demersal, this increases the probability of PPRs being implemented by 0.96pp, but there is no additional effect if the fish species is in a fully exploited fish stock.

The effect of the price on the probability of PPRs being implemented is negative and significant for all three specifications, so if accounted for the lags of *fully exploited*$_t$, for the type of the fishery and its interaction with *fully exploited*$_t$ or for the price interactions. The coefficients of the price variable are very small (from $-1.15*10^{-6}$ to $-1.92*10^{-6}$), however the price variable has an economic interpretation. A price increase of 1000$ per tonne of caught fish decreases the probability of PPRs being implemented by 0.12 to 0.19 percentage points, depending on the three different specifications. The coefficient for the interaction term between the price variable and *fully exploited*$_t$ is almost identical to the coefficient

[4] The demersal fisheries are chosen as the default type of the fishery. The other dummy variable for the type of the fish species, *GROUPpelagic*, was not included in the regression. The interaction effect between *fully exploited*$_t$ and *GROUPpelagic,* is opposite to the interaction effect between *fully exploited*$_t$ and *GROUPdemersal.*

of the price if accounted for the price interactions, however this coefficient is positive. A price increase of 1000$ per tonne of caught fish for fully exploited fish species increases the probability of PPRs being implemented by 0.19 percentage points. The interaction effects between *fully exploited*$_t$ and the four price categories are accounted for in column 3. With the exception of the effect of low priced fully exploited fish species, all other interaction effects are negative and significant at the 5% significance level. Fully exploited fish species that are medium priced decrease the probability of PPRs being implemented by 3.25 pp, while the species with a very high price decrease the probability of PPRs being implemented by 3.80 pp. So the higher the price category, the higher the decrease on the probability of PPRs being implemented. This is in line with the negative effect of the price on the probability of PPRs being implemented.

Table 5. The effects of ecological and economic conditions on PPRs being implemented for fully exploited fish stocks

Dependent variable *ppr_implemented_cc*	(1)	(2)	(3)
GDP per capita	-0.00530397	-0.00111032	-0.00011290
	(0.00433767)	(0.00330513)	(0.00337905)
Population growth	0.01193191***	0.00779634***	0.00903183***
	(0.00173396)	(0.00118390)	(0.00123866)
Trade openness	-0.00019722**	-0.00016219**	-0.00017934***
	(0.00008319)	(0.00006585)	(0.00006646)
Polity index	-0.00232905***	-0.00213198***	-0.00204977***
	(0.00029614)	(0.00024922)	(0.00024737)
Ratified int. environmental agreements	0.00579948	0.00199177	0.00034071
	(0.00525977)	(0.00402543)	(0.00397796)
(leave-out) Mean collapse rate	-0.08148639***	-0.07956920***	-0.07632048***
	(0.02053275)	(0.01825263)	(0.01651760)
World price	-0.00000171***	-0.00000115**	-0.00000192***
	(0.00000054)	(0.00000051)	(0.00000053)
Time	0.00291234***	0.00251996***	0.00274331***
	(0.00032014)	(0.00026153)	(0.00026612)
Fully exploited$_t$	-0.00023137	-0.00013286	0.03117308**
	(0.00183538)	(0.00259390)	(0.01334101)
Fully exploited$_{t-1}$	-0.00046179		
	(0.00111457)		
Fully exploited$_{t-2}$	0.00014881		
	(0.00091422)		
Fully exploited$_{t-3}$	0.00090090		
	(0.00106506)		
Fully exploited$_{t-4}$	0.00184020*		
	(0.00111450)		
Fully exploited$_{t-5}$	0.00358893*		
	(0.00186056)		
Demersal		0.00963865**	
		(0.00451376)	
Demersal × fully exploited		0.00856340	
		(0.00568817)	
World price × fully exploited			0.00000193**
			(0.00000075)
Low price × fully exploited			-0.02574924
			(0.01588515)
Medium price × fully exploited			-0.03253295**

			(0.01480609)
High price × fully exploited			-0.03468536**
			(0.01432929)
Very high price × fully exploited			-0.03798113**
			(0.01503958)
Observations	79,148	99,903	99,900
Country FE	YES	YES	YES
Species FE	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2 Overfished fish stocks

Table 6 presents the results from the three specifications for fish species that fall under the exploitation status *overfished*. The dummy variable $overfished_t$ is only significant if accounted for the price interactions. Fish stocks being overfished then decreases the probability of PPRs being implemented by 1.96 percentage points. If accounted for the lagged values of $overfished_t$, the table shows that $overfished_{t-1}$ and $overfished_{t-5}$ both have a small, positive effect on the probability of PPRs being implemented, but only at the 10% significance level (col. 1). This means that a fish stock being overfished one or five years before time *t* increases the probability of PPRs being implemented at time *t* by 0.23 or 0.51 percentage points, respectively. With the exception of GDP per capita and the number of ratified international environmental agreements, all control variables are significant again. The time trend variable is also significant and positive in all three specifications. This means that an increase in time by one year, will increase the probability of PPRs being implemented by 0.25-0.28 pp, depending on the specifications. The coefficients of the time variable for overfished fish stocks are slightly smaller compared to the coefficients for the fully exploited fish stocks.

If accounted for the type of the fishery and its interaction with $overfished_t$, the dummy variable *demersal* has a positive value, but is not significant (col.2). A fish species being demersal does not increase or decrease the probability of PPRs being implemented. The interaction term between $overfished_t$ and the type of fish species is significant, however. A fish species being demersal in overfished stocks increases the probability of PPRs being implemented by 2.79 percentage points.

The effect of the price on the probability of PPRs being implemented is negative and significant for all three specifications, so if accounted for the lags of $overfished_t$, for the type of the fishery and its interaction with $overfished_t$ or for the price interactions. The coefficients of the price variable are very small (from $-1.08*10^{-6}$ to $-1.72*10^{-6}$), however the price variable does have an economic interpretation. A price increase of 1000$ per tonne of caught fish decreases the probability of PPRs being implemented by 0.11 to 0.17 percentage points, depending on the three different specifications. The effect of the interaction term between the price and overfished fish stocks is also negative, but not significant (col. 3). The interaction effects between $overfished_t$ and the four price categories are accounted for in column 3. The price interaction effects are all significant at the 5% or 1% significance level, except for the high-priced overfished fish species, which is only significant at the 10% significance level. In contrast to the analysis of fully exploited fish species, in the analysis of overfished fish stocks there is no clear relationship between the effects of the different price interaction effects. Overfished fish species that are medium priced increase the probability of PPRs being implemented by 4.66 pp, while the overfished species with a high price increase the probability of PPRs being implemented by ‘only’ 2.11 pp. All price interaction effects are positive, in contrast to the negative price interactions for fully exploited fish stocks (see section 4.1) and the negative effect of the price on the probability of PPRs being implemented.

Table 6. The effects of ecological and economic conditions on PPRs being implemented for overfished fish stocks

Dependent variable *ppr_implemented_cc*	(1)	(2)	(3)
GDP per capita	-0.00498661	-0.00120090	-0.00025631
	(0.00433570)	(0.00329828)	(0.00341499)
Population growth	0.01192567***	0.00778596***	0.00909735***
	(0.00172294)	(0.00118406)	(0.00124062)
Trade openness	-0.00018701**	-0.00015227**	-0.00017505***
	(0.00008140)	(0.00006465)	(0.00006544)
Polity index	-0.00233123***	-0.00212663***	-0.00205351***
	(0.00029576)	(0.00024714)	(0.00024625)
Ratified int. environmental agreements	0.00542048	0.00199395	0.00038210
	(0.00525457)	(0.00400307)	(0.00396727)
(leave-out) Mean collapse rate	-0.08234903***	-0.08075234***	-0.07844467***
	(0.02047653)	(0.01829186)	(0.01648836)
World price	-0.00000172***	-0.00000112**	-0.00000108**
	(0.00000054)	(0.00000051)	(0.00000047)
Time	0.00283610***	0.00247205***	0.00269483***
	(0.00031872)	(0.00026093)	(0.00026603)
Overfished_t	0.00315146	-0.00396230	-0.01955098*
	(0.00225010)	(0.00505397)	(0.01121626)
Overfished_{t-1}	0.00229132*		
	(0.00136657)		
Overfished_{t-2}	0.00121203		
	(0.00116219)		
Overfished_{t-3}	0.00113571		
	(0.00136962)		
Overfished_{t-4}	0.00179731		
	(0.00154587)		
Overfished_{t-5}	0.00506907*		
	(0.00291800)		
Demersal		0.00612630	
		(0.00394090)	
Demersal × overfished		0.02788798***	
		(0.00901049)	
World price × overfished			-0.00000158
			(0.00000138)
Low price × overfished			0.03518598**
			(0.01446564)
Medium price × overfished			0.04661362***
			(0.01550583)
High price × overfished			0.02112591*
			(0.01223456)
Very high price × overfished			0.03278561**
			(0.01509257)
Observations	79,148	99,903	99,900
Country FE	YES	YES	YES
Species FE	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3 Collapsed fish stocks

Table 7 presents the results from the three specifications for fish species that fall under the exploitation status *collapsed*. The coefficients of the dummy variable $collapsed_t$ are negative and significant for all three specifications. A fish stock being collapsed at time *t* decreases the probability of PPRs being implemented at time *t* by 1.15, 2.08 or 4.52 percentage points, if accounted for the lagged values of $collapsed_t$, the type of the fishery and its interactions with $collapsed_t$ and for the price interactions respectively. With the exception of $collapsed_{t-3}$, all other lagged values of $collapsed_t$ are significant and negative if accounting for the lagged values of the exploitation status. A fish stock being collapsed one year or two years before time *t* decreases the probability of PPRs being implemented at time *t* by 0.44 or 0.24 pp, respectively. A fish stock being collapsed four or five years before time *t* decreases the probability of PPRs being implemented at time *t* by 0.51 or 1.07 percentage points, respectively. This shows that the exploitation status further back in time (at time *t-4* or *t-5*) has a larger effect on the probability of PPRs being implemented than the exploitation status at time *t*, *t-1* or *t-2*. As in the analyses of fully exploited and overfished fish stocks, all control variables are significant, except for the GDP per capita and the number of ratified international environmental agreements. The time trend variable is also significant and positive in all three specifications. This means that an increase in time by one year, will increase the probability of PPRs being implemented by 0.26-0.30 percentage points. The coefficients of the time variable for collapsed stocks are highest in comparison to the coefficients for the fully exploited and overfished fish stocks.

If accounted for the type of the fishery and its interaction with $collapsed_t$, the dummy variable *demersal* is significant and has a positive value (col. 2). A fish species being demersal increases the probability of PPRs being implemented by 1.12 percentage points. The interaction term between $collapsed_t$ and the type of fish species is insignificant and thus does not affect the probability of PPRs being implemented. This means that if a fish species is demersal, this increases the probability of PPRs being implemented by 1.12 percentage points, but there is no additional effect if the demersal fish species is in a collapsed stock.

The effect of the price variable on the probability of PPRs being implemented is negative and significant for all three specifications, so if accounted for the lags of $overfished_t$, for the type of the fishery and its interaction with $overfished_t$ or for the price interactions. The coefficients of the price variable are very small (from $-1.11*10^{-6}$ to $-1.72*10^{-6}$), however the price variable does have an economic interpretation. A price increase of 1000$ per tonne of caught fish decreases the probability of PPRs being implemented by 0.11 to 0.17 pp, depending on the three different specifications. The effect of the interaction term between the price and overfished fish stocks is also negative, but not significant (col.3). If accounted for the price interactions, the table shows that the interaction effects between collapsed fish stocks and the lowest two price categories, *low* and *medium*, are significant, however the latter only at the 10% significance level (col. 3). Collapsed fish species that have a low price increase the probability of PPRs being implemented by 4.41 pp, while collapsed fish species that have a medium price increase this probability of PPRs being implemented by 3.61 pp. As in the analysis of overfished fish stocks, the price interaction terms are positive for collapsed fish stocks, but it is in contrast to the negative effect of the price and the exploitation status *collapsed* on the probability of PPRs being implemented.

Table 7. The effects of ecological and economic conditions on PPRs being implemented for collapsed fish stocks

Dependent variable *ppr_implemented_cc*	(1)	(2)	(3)
GDP per capita	-0.00702208	-0.00161061	-0.00123336
	(0.00434810)	(0.00332180)	(0.00338525)
Population growth	0.01202775***	0.00789149***	0.00906169***
	(0.00172812)	(0.00119006)	(0.00124079)
Trade openness	-0.00019644**	-0.00016145**	-0.00018173***
	(0.00008159)	(0.00006513)	(0.00006563)
Polity index	-0.00230088***	-0.00212959***	-0.00203980***
	(0.00029574)	(0.00024866)	(0.00024579)
Ratified int. environmental agreements	0.00721591	0.00252276	0.00131059
	(0.00527471)	(0.00401158)	(0.00395672)
(leave-out) Mean collapse rate	-0.07032586***	-0.07021832***	-0.06271541***
	(0.01992383)	(0.01779872)	(0.01591881)
World price	-0.00000172***	-0.00000111**	-0.00000120**
	(0.00000054)	(0.00000051)	(0.00000051)
Time	0.00304017***	0.00259046***	0.00280173***
	(0.00032353)	(0.00026184)	(0.00026609)
Collapsed_t	-0.01151362***	-0.02073907***	-0.04519350***
	(0.00282779)	(0.00496805)	(0.01671291)
Collapsed_{t-1}	-0.00441680***		
	(0.00144566)		
Collapsed_{t-2}	-0.00244855*		
	(0.00133823)		
Collapsed_{t-3}	-0.00194243		
	(0.00144417)		
Collapsed_{t-4}	-0.00513278***		
	(0.00148871)		
Collapsed_{t-5}	-0.01073133***		
	(0.00290901)		
Demersal		0.01121472**	
		(0.00447725)	
Demersal × collapsed		-0.00070451	
		(0.00811913)	
World price × collapsed			-0.00000089
			(0.00000108)
Low price × collapsed			0.04412050**
			(0.02048263)
Medium price × collapsed			0.03606873*
			(0.01874525)
High price × collapsed			0.01879015
			(0.01666312)
Very high price × collapsed			0.00255660
			(0.01646328)
Observations	79,148	99,903	99,900
Country FE	YES	YES	YES
Species FE	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.4 Robustness Checks

This section presents some robustness checks that were done to test the sensitivity of the main results. All regressions done in the main analysis, are in this section conducted with the second dependent variable, *transition_into_ppr*. This variable captures the actual implementation of PPRs: the transition from no PPRs implemented in one year to PPR implementation in the next year. The corresponding regression tables can be found in Appendix C.1. The effect of the world price and its lagged values on the probability of PPR implementation will also be discussed.

4.4.1 Fully exploited fish stocks

Table C.1 in Appendix C.1 shows that dummy variable *fully exploited*$_t$ is not significant, as in the main analysis. While in the main analysis *fully exploited*$_{t-4}$ and *fully exploited*$_{t-5}$ increased the probability of PPRs being implemented by 0.18 and 0.36 percentage points respectively, if *transition_into_ppr* is used as dependent variable, *fully exploited*$_{t-3}$ increases the probability of PPR implementation by 0.12 percentage points. Most control variables are significant, with the exception of population growth. The (leave-out) mean collapse is significant only if accounted for the type of the fishery and its interactions with the exploitation status. The polity index is significant if accounted for the type of the fishery and its interactions with the exploitation status and for the price interactions. The time trend variable is positive and significant for all three specifications. This means that an increase in time by one year will increase the probability of PPR implementation by 0.016-0.017 pp, depending on the specifications, while in the main analysis the time variable increased the probability of PPRs being implemented by 0.25-0.29 pp.

The dummy variable *demersal*$_i$ is not significant if *transition_into_ppr* is used as dependent variable, while in the main analysis this increased the probability of PPRs being implemented by 0.96 percentage points. Again, the interaction effect between *fully exploited*$_t$ and *demersal* is not significant. The effect of the price on the probability of PPR implementation is negative and significant for all three specifications, although only at the 10% significance level. An increase of 1000$ per tonne of caught fish decreases the probability of PPR implementation by 0.0064-0.011 pp, while in the main analysis this decreased the probability of PPRs being implemented by 0.12-0.19 pp, depending on the specifications. With *transition_into_PPRs* as dependent variable, the price interaction of *fully exploited*$_t$ and price category *high price* is negative and significant. Fully exploited fish species that are high priced decrease the probability of PPR implementation by 0.11 percentage points. In the main analysis, all price interactions except for the low-price species were negative and significant.

4.4.2 Overfished fish stocks

Table C.2 in Appendix C.1 shows that dummy variable *overfished*$_t$ is positive and significant at the 10% significance level, while this variable was insignificant in the main analysis. A fish stock being overfished at time *t* increases the probability of PPR implementation by 0.11 percentage points. While in the main analysis *overfished*$_{t-1}$ and *overfished*$_{t-5}$ both increased the probability of PPRs being implemented, if *transition_into_ppr* is used as dependent variable, *overfished*$_{t-3}$ decreases the possibility of PPR implementation by 0.12 percentage points. Just as in table C.1, most control variables are significant, except for population growth, and the polity index and the (leave-out) mean collapse, if accounted for the lagged values of *overfished*$_t$. Again, the time trend variable is positive and significant for all three specifications. An increase in time by one year, will increase the probability of PPR implementation by 0.016-0.017 pp, while this was 0.25-0.28 pp in the main analysis.

In the regressions with *transition_into_ppr* as dependent variable, variable *demersal*$_i$ and the interaction between demersal and *overfished*$_t$ are positive, but insignificant, while this interaction term was positive and significant in the main analysis. The effect of the price on the probability of PPR implementation is negative and only significant at the 10% significance level if accounted for the lagged values of *overfished*$_t$. An increase of 1000$ per tonne of caught fish decreases the probability of PPR implementation by 0.0080 pp, while in the main analysis this decreased the probability of PPRs being implemented by 0.11-0.17 pp, depending on the specifications. All price interactions are insignificant, while these were all significant in the main analysis.

4.4.3 Collapsed fish stocks

Table C.3 in Appendix C.1 shows that the dummy variable *collapsed*$_t$ is not significant, while it was significant in the main analysis. Lagged values *collapsed*$_{t-2}$ and *collapsed*$_{t-4}$ are still significant, while the in the main analysis all lagged values except for *collapsed*$_{t-3}$ were significant. What should be noted is that the coefficients from the regression with *transition_into_PPRs* as dependent variable are (absolute) smaller compared to the coefficients from the regressions with *ppr_implemented_cc*: -0.00098 vs -0.0024 for *collapsed*$_{t-2}$ and -0.0021 vs -0.0051 for *collapsed*$_{t-4}$. The control variables GDP per capita, trade openness, the number of ratified international environmental agreements and the polity index, except if accounted for the lagged variables of the exploitation status, are significant. Again, the time trend variable is positive and significant for all three specifications. An increase in time by one year, will increase the probability of PPR implementation by 0.016-0.017 pp, while this increase in the probability of PPRs being implemented was 0.26-0.30 pp in the main analysis. Just like in the main analysis, the coefficients of the time variable for collapsed stocks if *transition_into_ppr* is used as dependent variable are slightly higher compared to the coefficients for the fully exploited and overfished fish stocks.

A fish species being demersal increases the probability of PPR implementation by 0.058 percentage points, while it increased the probability of PPRs being implemented by 1.12 percentage points in the main analysis. The interaction effect between *collapsed*$_t$ and *demersal* is not significant, as was the case in the main analysis. The effect of the price on the probability of PPR implementation is negative and only significant at the 10% significance level if accounted for the lagged values of *collapsed*$_t$. An increase of 1000$ per tonne of caught fish decreases the probability of PPR implementation by 0.0082 pp, while in the main analysis this decreased the probability of PPRs being implemented by 0.11-0.17 pp, depending on the specifications. If *transition_into_PPRs* is used as dependent variable, all price interactions are insignificant, in contrast to the two significant interactions for low- and medium-priced collapsed fish stocks in the main analysis.

The results from the regressions with *transition_into_PPRs* as dependent variable are quite in line with the results from the main analysis for fully exploited, overfished and collapsed fish stocks. Most coefficients of the variables coming from the regressions *transition_into_PPRs* are smaller than the coefficients in the main analysis, sometimes even by a factor ten or twenty. This could be explained by the lower number of '1's of the variable *transition_into_PPRs* compared to variable *ppr_implemented_cc*: 187 vs. 2678, respectively. Some variables that were significant in the main analysis were not significant anymore in the analysis with *transition_into_PPRs*. This is probably due to the lower coefficients and the relatively high standard errors in the analysis with *transition_into_PPRs*. However, no major conflicting results have emerged from this analysis and overall the evidence is quite in line with the results from the main analysis. This makes the main analysis seem to be adequate.

4.4.4 (lagged) World price

Appendix C.2 contains regression tables for fully exploited, overfished and collapsed fish stocks, accounting for the exploitation statuses and the lagged values of the world price. These results can be used to determine whether the price of the fish species, from time *t-5* to time *t-1*, can be used to explain PPRs being implemented at time *t*. These regressions are conducted with variable *ppr_implemented_cc* (col. 1) and *transition_into_PPRs* (col. 2) as dependent variable.

For each exploitation status, the lagged variables of the price variable that are significant are the same. The price at time *t-1* and at time *t-5* have a negative effect on the probability of PPRs being implemented. An increase of 1000$ per tonne of caught fish in the price at time *t-1* decreases the probability of PPRs being implemented by 0.097, 0.099 or 0.10 percentage points, for fully exploited, overfished and collapsed fish stocks respectively. An increase of 1000$ per tonne of caught fish in the price at time *t-5* decreases the probability of PPRs being implemented by 0.16 pp for fully exploited fish stocks and 0.15 pp for overfished and collapsed fish stocks. A change in the price at time *t-5* thus has a larger effect on the probability of PPRs being implemented than at time *t-1*. If *transition_into_PPRs* is used as dependent variable (col. 2), the price at time *t-4* has a positive and significant effect for each exploitation status. An increase of 1000$ per tonne of caught fish in the price at time *t-4* increases the probability of PPRs being implemented by 0.026 percentage points for fully exploited, overfished and collapsed fish stocks.

The negative effect of the lagged values of the world price if *ppr_implemented_cc* is used as dependent variable correspond to the negative effect of the price on the probability of PPRs being implemented from the main analysis. The positive effect of $\textit{world price}_{t-4}$ if *transition_into_PPRs* is used as dependent variable is in contrast with the negative effects of the price elsewhere in the analysis. However, overall the results from these regressions accounting for lagged values of the price are quite in line with the results from the main analysis.

In order to further assess the effect of the price on PPRs being implemented, multiple graphs were made using the *marginsplot* command in STATA, which are depicted in figure 2. Figure 2 shows a graphical overview of the relationship between the price of fish species and the linear prediction of PPRs being implemented for pelagic and demersal fish species. The figures of the linear models, figure a, b, c and d, show that for both pelagic and demersal fish species, fish species that have a lower price are more likely of PPRs being implemented than fish species that are higher priced. At the same value of the price, the linear prediction of PPRs being implemented is higher for demersal fish species, which corresponds to the findings from the main analysis. The linear prediction of PPRs being implemented is higher for the left column in which *ppr_implemented_cc* is used as dependent variable compared to the graphs in which *transition_into_PPRs* is the dependent variable. This was in line with the expectations due to the different specifications of the dependent variables. In figures e and f, in which the exponent of the price is included ($price^2$), the linear prediction of PPR implementation decreases as the price increases to around 15000 US$, but as the price increases further, the probability of PPR implementation also increases slightly.

There is quite some overlap in the confidence intervals of the graphs of pelagic fish species and demersal fish species. While non-overlapping confidence intervals of two statistics imply statistical significance, the inverse, overlapping confidence intervals, do not necessarily mean a lack of statistical insignificance. The confidence intervals are wider for the higher values of the price.

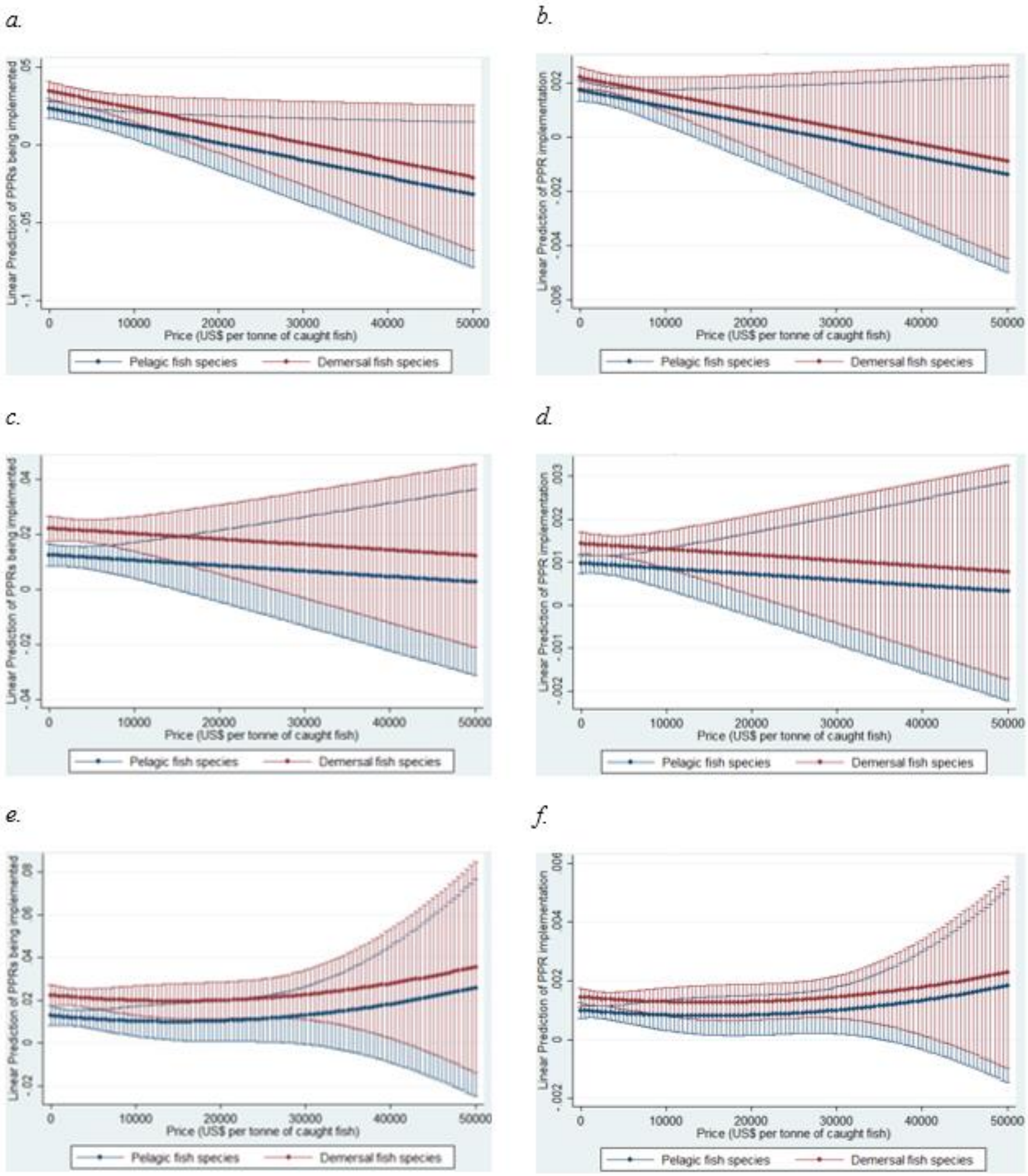

Figure 2. Graphical overview of the relationship between the (world) price of fish species and PPRs being implemented by the type of the fishery for different regression models.

Values of PPR implementation are estimated as a linear function of estimated values from different equations. In the first column, consisting of figure a, c and e, ppr_implemented_cc is used as dependent variable. Figures b, d and f show the plots in which transition_into_PPRs is used as dependent variable. All regressions have the same specifications concerning clusters and fixed effects as in the main analysis. In each row, a different regression model is used. For figure a and b, predictions come from a fitted regression model which included the dummy variable indicating the type of the fishery, the price, set of control variables, the different categories of exploitation status and the time trend. For figures c and d, the regression model only included the dummy variable indicating the type of the fishery and the price, being a reduced version of the model used for figures a and b. The regression model used for figures e and f was a non-linear model which included the dummy variable indicating the type of the fishery and the squared value of the price, so worldprice^2.

5. Discussion

In this chapter, the results laid out above will be interpreted and their contribution towards finding the determinants of PPR adoption in fisheries management will be discussed. The results will also be compared to findings from the literature. Then some limitations of the study will be discussed and recommendations for future research will be given.

5.1 Exploitation status of the stock

The results indicated that for fully exploited and overfished fish stocks, the exploitation status at time *t* does not affect the probability of PPRs being implemented. This was not expected, since it was hypothesized that that a fish stock being close to stock depletion increases the probability of PPRs being implemented in the fishery. However, some lagged values of the exploitation statuses *fully exploited* and *overfished* do have a small positive effect on the probability of PPRs being implemented. For fully exploited fish stocks, the exploitation status at time *t-4* or *t-5* increases the probability of PPR implementation at time *t*, while the exploitation status at time *t-1* or *t*-5 is significant in increasing the probability of PPRs being implemented for overfished fish stocks. The significant positive effects of these lagged values of the exploitation status can be explained by the concepts of the political economy and responsive governance: conditions from a few years before time *t* can be determinants of PPR implementation at time *t* because of a delay in policy measures taken concerning environmental problems (Quaas et al., 2018; Webster, 2015). Since these decisions are often only taken looking back, it makes sense that the lagged values of the exploitation status are significant, while the exploitation status in the same year as the PPR implementation is not. However, it is rather difficult to give an explanation for the significance of these exact years compared to the other lagged values. For collapsed fish stocks, the exploitation status and most of its lagged values decrease the probability of PPRs being implemented.

Thus, while lagged values of the exploitation status have a positive effect on the probability of PPRs being implemented for fully exploited and overfished fish stocks, the exploitation status and its lagged values have a negative effect on the probability of PPRs being implemented for collapsed fish stocks. These results are to some extent in line with the hypothesis that a fish stock being close to stock depletion increases the probability of PPRs being implemented in the fishery. According to Webster (2015), Arnason (1993), Neher et al. (1989) and Isaksen and Richter (2019), institutional change is often only undergone in times of a crisis, such as a severe stock depletion, as a final measure to rescue a fishery. This would explain why the effect of some lagged values of the exploitation status *fully exploited* and *overfished* increase the probability of PPRs being implemented, since these fish stocks are heading to stock depletion. In line with this argument, collapsed fish stocks are already too far on the path heading to stock depletion and thus lack the potential to return to a good state of the stock, explaining the decrease in the probability of PPRs being implemented. Based on this argument, taking action is more urgent for overfished fish stocks compared to fully exploited fish stocks, since overfished fish stocks are closer to collapse, which would imply a higher effect for overfished stocks compared to fully exploited stocks. However, the results showed that there is not much of a difference between the effects of the lagged values of the exploitation status for fully exploited and overfished fish stocks. By showing the positive effects of lagged values of the exploitation status for fully exploited and overfished fish species and the negative effect of (the lagged values of) the exploitation status for collapsed fish stocks on the probability of PPRs being implemented, this research contributes to a clearer understanding of the effect of the exploitation status on the implementation of PPRs.

5.2 Type of the fish species

If fish species are demersal, this increases the probability of PPRs being implemented by 0.96 or 1.12 percentage points for fully exploited and collapsed fish stocks, respectively. The effect for pelagic fish species is opposite to the effect for demersal fish species, so a fish species being pelagic decreases the probability of PPRs being implemented by 0.96 or 1.12 pp for fully exploited and collapsed fish stocks respectively. If accounted for the overfished fish stocks, a fish species being demersal does not affect the probability of PPRs being implemented. However, if the fish species are both demersal and overfished, this increases the probability of PPRs being implemented by 2.79 percentage points.

The results concerning the type of the fish species are in line with the hypothesis that a fishery being demersal increases the probability of PPRs being implemented. This inevitably means that pelagic fish species decrease the probability of PPRs being implemented, which matches with the claims made in Isaksen and Richter (2019) that migratory species, as pelagic fish species, are less likely to be managed by a quota system. For fish stocks that are both overfished and demersal, there is a bigger increased probability of PPRs being implemented. An explanation for this enhanced interaction effect might be that overfished fish stocks are closest to stock depletion, without the situation already gone too far and the fish stock being collapsed. Together with demersal fish species' increased probability of PPRs being implemented, this could explain fish stocks that are both overfished and demersal having an increased probability of PPRs being implemented compared to fully exploited and collapsed demersal fish species. By showing that demersal fisheries have a higher probability of PPRs being implemented, this research provided the first empirical evidence for the effect of the type of the fishery on the probability of PPR implementation. These results provided new insights in the determinants of PPR adoption.

5.3 Value of the fish species

The effect of the price on the probability of PPRs being implemented is negative, but the size of the effect differs: an increase of 1000$ in the price per tonne of caught fish decreases the probability of PPRs being implemented by 0.11-0.19 percentage points, depending on the specifications. These results are contradictory to the hypothesis that an increase in the price of fish species will have a positive effect on the probability of PPRs being implemented in the fishery. The results from this study do not fit with a theory suggested by Isaksen and Richter (2019) that there is a stronger economic incentive to implement PPRs for fish species with a higher value, since more can be gained from this fishery. An explanation for the negative effect of the price on the probability of PPRs being implemented could be in line with the idea of Kaffine (2009) and Isaksen and Richter (2019) that fish species with a higher price could be under more pressure by fishermen, which would require higher efforts in monitoring and enforcement. This implies higher costs, thus making it less attractive for PPRs to be implemented for higher value fish species (Isaksen & Richter, 2019; Kaffine, 2009).

The interaction between the price and the exploitation status *fully exploited* is significant, in contrast to the interactions between the price and the two other exploitation statuses. A price increase of 1000$ per tonne of caught fish for fully exploited fish species increases the probability of PPRs being implemented by 0.19 percentage points. The effect of the price interactions, combinations between the price categories and the exploitation statuses, on the probability of PPRs being implemented differs for the different exploitation statuses. The price interactions have a significant negative effect for fully exploited fish stocks: Medium, high or very high priced fully exploited fish stocks decrease the probability of PPRs being implemented by 3.25, 3.47 or 3.80 percentage points, respectively. This negative effect might be explained by the negative effect of the price and the negative, but insignificant, effect of the exploitation status *fully exploited* at time *t*. In further research it would be interesting to see what the effect of the interaction between the price categories and the significant lagged values (at time *t-4* and *t-5*) of the exploitation status *fully exploited* would be. Since these lagged values had a positive effect on the probability of PPRs being implemented, it would be expected that the interaction effect then would be smaller. For overfished fish stocks, all price interactions have a positive effect on the probability of PPRs being implemented, in contrast to the negative effects of for fully exploited fish stocks. Overfished fish stocks that are low, medium, high or very high priced all increase the probability of PPRs being implemented by 3.52, 4.66, 2.11 or 3.82 percentage points, respectively. These effects are rather difficult to explain, since the effect of the price is negative and the effect of $overfished_t$ on PPRs being implemented is slightly positive, but insignificant. Besides, there is no clear pattern visible in the size and the order of the effects. The effect of the price interactions for collapsed fish stocks on PPR implementation are also positive. Collapsed fish stocks that are low- or medium-priced increase the probability of PPRs being implemented by 4.41 or 3.61 percentage points, respectively. These positive effects of the price interactions are quite unexpected, because of negative effect of the price and the negative effect of the exploitation status *collapsed* on the probability of PPRs being implemented. These results add to the research on the determinants of PPR implementation by showing that fish species that have a higher price, have a lower probability of PPRs being implemented. The effects of the price interactions are less clear however, and further research is needed to fully understand how the price categories and the exploitation statuses interact. It could also be interesting to include variables on the profitability of the fisheries in the analysis to investigate the hypothesis that a higher price of fish species results in higher PPR implementation because of protection of the profitability.

5.4 Limitations of the research

This research also has some limitations. When establishing causal inference, the omitted variable bias and reversed causality are two major threats, also in this research. Fixed effects models control for the omitted variables, by removing all time-invariant unit specifics from the analysis. When analysing the effects of the exploitation status of the stock and the value of the fish species on the probability of PPR implementation, fixed effects were applied on the species and country level. However, in the analysis of the effect of the type of the fishery on the probability of PPR implementation, fixed effects could not be applied on the species level, since the type of the fishery does not change over time and this characteristic would then also be removed from the analysis. Failing to control for the species-specific effect could lead to some of these species' characteristics influencing PPR implementation, resulting in the wrong estimate of the causal effect of the type of the fish species on PPR implementation. Even though this potential omitted variable bias could lead to wrong estimates, there was no other, simple way to determine the effect of the type of the fish species on PPR implementation, so this possible flaw in the estimation should be taken for granted.

The other potential threat to establishing causal inference in this research is reversed causality: PPR implementation could also have an effect on the exploitation status of the stock and the price of the fish species. Controlled randomized experiments are often considered as the best method to determine causal inference, however in most cases, as in this research, only observational data is available, so randomized controlled trials are not possible. A difference-in-difference (DiD) strategy is also often used in determining causal inference, however, in this research it would have been difficult to determine the treatment and the control group, since PPR implementation could not be chosen as the treatment because it is already the outcome variable. Instrumental variable (IV) methods could also be used, however this method appeared unsuccessful in determining the effect of a stock collapse on the implementation of PPRs (Isaksen & Richter, 2019)[5]. Since these methods were not suitable for this research, the multiple

[5] Preliminary version, updated May 31, 2015

level fixed effects model was chosen. Including lagged values of the independent variable in the regression is a way of dealing with reverse causality, which is done with the exploitation statuses in the main analysis and with the price in the robustness checks. In this way, reversed causality is handled in the best way possible. In further research, the effect of the three ecological and economic conditions could also be estimated by other estimation techniques. Leszczensky and Wolbring (2019) claim that the maximum likelihood (ML) method implemented in a structural equation modelling (SEM) framework including a contemporaneous and a lagged effect of the independent variable on the outcome variable provides good estimates of these effects. It would be interesting to compare these results with the results from this research and to determine whether the results of this research are biased because of potential endogeneity problems. However, the ML-SEM also deals with problems of large standard errors and based estimates in case of serial correlation and additional challenges may arise in cases of missing data and interaction effects (Leszczensky & Wolbring, 2019). There might be solutions to these problems, but that is beyond the scope of this research for now.

Another limitation of the research could be the generalizability of the results. Since fixed effects models are estimated by using only within variation, there is a larger reduction in the variation and the opportunity to explain the variation between units is forgone. This means that this research cannot explain why in some fishery in Europe PPRs were adopted while PPRs were not adopted in another fishery in the Caribbean. In this research, finding the determinants of PPR implementation was the main aim, so the exclusion of the variation between countries did not matter much. However, explanations on the global differences in PPR implementation remain to be uncertain, so in further research it would be interesting to take the variation between countries into account to get a more complete overview of PPR implementation.

6. Conclusions

The establishment of private property rights is a broadly advocated policy tool in order to increase economic efficiency in in fisheries management. The adoption of PPRs as ITQs is seen as the solution to the problems that fisheries are facing globally: decreasing fish stocks, overcapitalization and ecosystem disruption. Only 10% of the global fish harvest is managed by ITQs, so the broad adoption of ITQs is lagging behind. This inconsistency between economic theory and real life together with the lack of empirical research on the determinants of PPR adoption led to the main research question of this thesis: *Which ecological and economic conditions affect the adoption of private property rights in fisheries management?* These ecological and economic conditions were the exploitation status of the stock, the type of the fish species and the value of the fish species. Various binary outcome models with multiple high-dimensional fixed effects were estimated by the *reghdfe* command in STATA to calculate the effect of the three ecological and economic conditions.

The exploitation status of the stock had different effects on the probability of PPR implementation for its different categories. A fish species being collapsed at time *t* decreased the probability of PPRs being implemented at time *t* by 1.15 percentage points if accounted for lagged values of the exploitation status. Lagged values of the exploitation status *collapsed* decreased the probability of PPRs being implemented by 0.24-1.07 percentage points, depending on time specifications. This negative effect of the exploitation status *collapsed* on the probability of PPRs being implemented can be explained by the lack of potential that collapsed fish stocks have to return to a good state, making the exploitation status *collapsed* a negative determinant. For fully exploited and overfished fish stocks, some lagged values increased the probability of PPRs being implemented by 0.18-0.51 percentage points, depending on the time specifications. The positive effect of the lagged values of exploitation statuses *fully exploited* and *overfished* can be explained by the trend that decision making on policy measures concerning environmental problems is often postponed or delayed.

This research has also shown that if fish species are demersal, this increased the probability of PPRs being implemented by 0.96 or 1.12 percentage points, if accounted for the exploitation statuses *fully exploited* and *collapsed*, respectively. This implied that fish species being pelagic decreased the probability of PPRs being implemented by the same percentage. If accounted for the type of the fishery and its interaction with the exploitation status *overfished*, demersal fish species in an overfished fish stock increased the probability of PPRs being implemented by 2.79 percentage points. This enhanced interaction effect might be explained by the already positive effects of the exploitation status *overfished* and demersal as the type of the fish species separately, together with the high urgency for overfished fish stocks, being closest to collapse, for PPR implementation as final measure to rescue the fish stocks.

The price of fish species had a negative effect on the probability of PPRs being implemented. An increase of 1000$ in the world price per tonne of caught fish decreased the probability of PPRs being implemented by 0.11-0.19 percentage points, depending on the different specifications and exploitation statuses. This negative effect of the price on the probability of PPRs being implemented could be explained by the higher pressure on higher value fish species because of potential higher profits, requiring higher efforts in monitoring and enforcement and implying higher costs. This could make PPR implementation less attractive for higher value fish species. Several price interactions between the price categories and the exploitation statuses did appear to be significant. Fully exploited fish stocks that are medium, high or very high priced decreased the probability of PPRs being implemented by 3.25, 3.47 or 3.80 percentage points, respectively. For fully exploited fish stocks, it can be concluded that the higher the price (category), the more negative is the effect, which is in line with the negative effect of the price on the probability of PPRs being implemented. However, overfished stocks that are low, medium, high or very high priced all increased the probability of PPRs being implemented by 3.52, 4.66, 2.11 or 3.28 percentage points, respectively. This is in contrast to the negative effect of the price, but in line with the positive effect of the lagged values of the exploitation status *overfished*. Collapsed fish stocks that are low or medium priced increased the probability of PPRs being implemented by 4.41 or 3.61 percentage points, respectively. This is in contrast to the negative effect of the price and the negative effect of the exploitation status *collapsed* on the probability of PPRs being implemented.

This research contributed to the field of research of private property rights in fisheries management by providing empirical evidence on the causal effect of three ecological and economic conditions, being the exploitation status of the stock, the type of the fish species and the value of the fish species, on the implementation of private property rights. The size of the found effects may seem small, however, the probability of PPR adoption was rather small as well, since in only 2.95% of the fisheries in the data sample PPRs were adopted between 1950 and 2006. The results of this research help to better understand determinants of PPR adoption. By researching the determinants of PPR adoption, this research had another focus than most studies in the field of rights based systems in fisheries, that mainly focus on the assessment of the effectiveness of PPR implementation. This research provided some evidence on the determinants of PPR adoption and is thus a solid basis for further research on this topic. However, other types of research as RCTs or case studies are needed to produce qualitative evidence to better understand the process of the adoption of private property rights.

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Appendix A. Data description

A.1 Summary statistics by region

Table A.1. Summary Statistics by region: Africa

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	31761	0.002	0. 046	0	1
Transition into PPRs (0,1)	31761	0.0002	0.015	0	1
Species-level data:					
World price (US$ per tonne)	31761	2477.763	2406.037	45.55444	50415.04
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	31734	0.180	0.182	0	1
Country-level data:					
GDP/ capita, log	23820	6.912	1.040	3.913	10.581
Population growth, %	27085	0.798	0.535	-5.229	2.402
Trade openness, %	23516	69.679	30.990	6.320	280.361
Polity (-10,10)	24686	-2.596	5.963	-9	10
environmental agreements, log	30654	2.067	1.230	0	4.970

Table A.2. Summary Statistics by region: Caribbean

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	8616	0	0	0	0
Transition into PPRs (0,1)	8616	0	0	0	0
Species-level data:					
World price (US$ per tonne)	8616	2620.79	2007.624	51.39574	14696.33
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	8592	0.137	0.179	0	1
Country-level data:					
GDP/ capita, log	5041	8.883	0.903	6.153	10.545
Population growth, %	6997	-0.028	1.004	-4.496	2.481
Trade openness, %	5562	91.524	35.746	24.950	182.497
Polity (-10,10)	3742	6.662	5.445	-10	10
environmental agreements, log	7464	1.898	1.418	0	4.970

Table A.3. Summary Statistics by region: Eastern Europe and Central Asia

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	15256	0.004	0.064	0	1
Transition into PPRs (0,1)	15256	0.0003	0.018	0	1
Species-level data:					

World price (US$ per tonne)	15256	2364.267	3049.761	27.97	50415.04
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	15256	0.162	0.171	0	1
Country-level data:					
GDP/ capita, log	7320	8.508	0.601	6.522	10.039
Population growth, %	10164	-0.220	0.821	-3.837	1.562
Trade openness, %	6711	65.485	37.309	8.333	172.902
Polity (-10,10)	8637	4.009	6.286	-8	10
environmental agreements, log	15256	2.329	1.243	0	4.489

Table A.4. Summary Statistics by region: Latin America

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	10125	0.008	0.087	0	1
Transition into PPRs (0,1)	10125	0.001	0.033	0	1
Species-level data:					
World price (US$ per tonne)	10125	2176.083	1879.142	48.03	14696.33
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	10112	0.156	0.147	0	1
Country-level data:					
GDP/ capita, log	9167	8.136	0.532	6.687	9.006
Population growth, %	9167	0.584	0.697	-3.809	1.331
Trade openness, %	9176	48.993	27.138	15.880	198.767
Polity (-10,10)	9910	2.464	6.425	-9	10
environmental agreements, log	10125	2.755	0.830	0	4.127

Table A.5. Summary Statistics by region: Middle East

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	9092	0	0	0	0
Transition into PPRs (0,1)	9092	0	0	0	0
Species-level data:					
World price (US$ per tonne)	9092	2658.747	2827.338	81.98	40636.42
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	9092	0.092	0.105	0	0.5
Country-level data:					
GDP/ capita, log	6583	8.393	1.435	5.781	11.314
Population growth, %	7926	1.026	0.683	-3.648	2.840
Trade openness, %	6319	69.592	24.146	13.772	149.453
Polity (-10,10)	7604	-3.850	6.874	-10	10
environmental agreements, log	9092	2.324	1.024	0	4.060

Table A.6. Summary Statistics by region: Oceania and the Pacific

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	12603	0.047	0.212	0	1
Transition into PPRs (0,1)	12603	0.003	0.058	0	1
Species-level data:					
World price (US$ per tonne)	12603	3212.702	1992.454	48.6	21464.34
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	12582	0.104	0.198	0	1
Country-level data:					
GDP/ capita, log	4063	8.843	1.331	6.303	10.581
Population growth, %	10582	0.571	0.908	-5.229	2.547
Trade openness, %	4135	68.957	25.267	24.819	158.875
Polity (-10,10)	3747	8.981	2.252	-3	10
environmental agreements, log	6199	2.135	1.395	0	4.970

Table A.7. Summary Statistics by region: South and East Asia

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	21993	0.013	0.113	0	1
Transition into PPRs (0,1)	21993	0.0001	0.013	0	1
Species-level data:					
World price (US$ per tonne)	21993	1863.781	1701.495	31.68	18875.05
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	21991	0.090	0.105	0	1
Country-level data:					
GDP/ capita, log	16527	7.570	1.670	4.449	10.502
Population growth, %	18743	0.414	0.699	-4.668	1.698
Trade openness, %	16597	68.266	74.215	0.309	436.958
Polity (-10,10)	18811	0.667	7.370	-10	10
environmental agreements, log	21993	1.978	1.166	0	3.892

Table A.8. Summary Statistics by region: Western Europe and North America

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	53501	0.030	0.170	0	1
Transition into PPRs (0,1)	53501	0.002	0.047	0	1
Species-level data:					
World price (US$ per tonne)	53501	2376.096	2741.177	30.26	50415.04
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	53500	0.162	0.123	0	1
Country-level data:					
GDP/ capita, log	42215	10.100	0.528	8.006	11.782

Population growth, %	44048	-0.545	0.913	-6.445	1.427
Trade openness, %	42437	58.236	31.379	9.305	188.978
Polity (-10,10)	45722	8.860	3.831	-9	10
environmental agreements, log	52191	3.351	0.938	0	4.970

A.2 Summary statistics by region (commercial) importance

Table A.9. Summary Statistics by (commercial) importance: Commercial fisheries

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	71522	0.013	0.112	0	1
Transition into PPRs (0,1)	71522	0.001	0.030	0	1
Species-level data:					
World price (US$ per tonne)	71522	2631.627	2476.371	27.97	50415.04
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	71511	0.144	0.146	0	1
Country-level data:					
GDP/ capita, log	50451	8.671	1.587	3.913	11.782
Population growth, %	59363	0.140	0.994	-6.445	2.840
Trade openness, %	50286	63.204	37.394	0.309	436.958
Polity (-10,10)	54126	3.779	7.348	-10	10
environmental agreements, log	66969	2.623	1.242	0	4.970

Table A.10. Summary Statistics by (commercial) importance: Highly commercial fisheries

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	73776	0.023	0.149	0	1
Transition into PPRs (0,1)	73776	0.001	0.038	0	1
Species-level data:					
World price (US$ per tonne)	73776	2196.654	2502.589	30.26	30619.11
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	73700	0.144	0.162	0	1
Country-level data:					
GDP/ capita, log	51032	8.497	1.638	3.913	11.782
Population growth, %	59507	0.186	0.962	-6.445	2.840
Trade openness, %	50773	65.362	45.124	0.309	436.958
Polity (-10,10)	55539	3.147	7.539	-10	10
environmental agreements, log	70781	2.426	1.267	0	4.970

Table A.11. Summary Statistics by (commercial) importance: Minor commercial fisheries

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	16080	0.005	0.069	0	1
Transition into PPRs (0,1)	16080	0.001	0.027	0	1
Species-level data:					
World price (US$ per tonne)	16080	2393.94	2333.162	48.03	28812.13
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	16079	0.164	0.138	0	1
Country-level data:					
GDP/ capita, log	12366	8.867	1.540	3.913	11.782
Population growth, %	14491	0.174	0.999	-6.445	2.798
Trade openness, %	12472	65.068	39.694	0.309	436.958
Polity (-10,10)	12311	4.704	7.057	-10	10
environmental agreements, log	14227	3.043	1.164	0	4.970

Table A.12. Summary Statistics by (commercial) importance: NA

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	630	0.038	0.192	0	1
Transition into PPRs (0,1)	630	0.002	0.040	0	1
Species-level data:					
World price (US$ per tonne)	630	2594.378	2040.335	46.86	12189.95
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	630	0.106	0.130	0	0.824
Country-level data:					
GDP/ capita, log	269	9.226	1.011	7.816	11.109
Population growth, %	534	0.764	0.740	-3.619	2.547
Trade openness, %	287	62.287	30.707	9.305	183.810
Polity (-10,10)	298	4.661	7.009	-10	10
environmental agreements, log	329	2.971	1.132	0	4.970

Table A.13. Summary Statistics by (commercial) importance: Of no interest

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	139	0	0	0	0
Transition into PPRs (0,1)	139	0	0	0	0
Species-level data:					
World price (US$ per tonne)	139	1422.353	1211.735	341.58	5590.79
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	139	0.262	0.098	0.032	0.530
Country-level data:					
GDP/ capita, log	131	10.221	0.709	8.263	11.109

Population growth, %	124	-0.270	0.747	-3.166	0.869
Trade openness, %	130	62.731	30.342	19.359	152.029
Polity (-10,10)	122	8.000	5.397	-9	10
environmental agreements, log	131	3.995	0.493	2.639	4.673

Table A.14. Summary Statistics by (commercial) importance: Subsistence fisheries

Variable	count	mean	sd	min	max
Fishery-level data:					
Implementation of PPRs (0,1)	800	0	0	0	0
Transition into PPRs (0,1)	800	0	0	0	0
Species-level data:					
World price (US$ per tonne)	800	1936.887	1873.495	75.65	7283.02
EEZ-level data:					
(leave-out) Mean collapse rate (0,1)	800	0.130	0.127	0	0.556
Country-level data:					
GDP/ capita, log	487	9.076	1.473	5.510	11.109
Population growth, %	693	0.293	1.028	-5.229	2.547
Trade openness, %	505	62.375	31.224	10.481	183.810
Polity (-10,10)	463	5.030	6.909	-10	10
environmental agreements, log	537	2.861	1.452	0	4.970

Appendix B. Hausman test

Table B.1. Output table of the Hausman test

	Coefficients (b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
developing	-.0063533	-.0052558	-.0010976	.0001403
fully_expl~d	-.012489	-.0098571	-.0026319	.0002772
overfished	-.0033228	.0002789	-.0036016	.0003771
recovering	-.0120088	-.0108607	-.0011481	.0002965
collapsed	-.0193232	-.0150188	-.0043044	.0005377
realprice_~n	-9.37e-07	-1.02e-06	8.50e-08	4.94e-08
time	.0023605	.0025096	-.0001492	.0000492
nlgdp_capi~c	-.0037004	-.0008252	-.0028752	.0012476
npop_growth	.0099811	.0081222	.0018589	.0002575
ntrade	-.0001661	-.0002263	.0000602	.0000154
npolity2	-.0021242	-.0017214	-.0004028	.0000342
nlieanumag~m	.0072832	-.0004166	.0076998	.000807
nmeancolla~2	-.0105932	-.0065405	-.0040528	.0011911

```
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                           =      477.63
                Prob>chi2 =      0.0000
```

Appendix C. Robustness Checks

C.1 Regressions with transition_into_PPRs as dependent variable

Table C.1. The effects of ecological and economic conditions on PPR implementation for fully exploited fish stocks

Dependent variable *transition_into_PPRs*	(1)	(2)	(3)
GDP per capita	0.001448564***	0.001056541***	0.001189144***
	(0.000412231)	(0.000324696)	(0.000326569)
Population growth	-0.000342425	-0.000099863	-0.000068142
	(0.000347857)	(0.000250169)	(0.000254720)
Trade openness	-0.000032639***	-0.000023656***	-0.000024476***
	(0.000007862)	(0.000006473)	(0.000006408)
Polity index	-0.000010065	-0.000043728**	-0.000035916*
	(0.000023995)	(0.000020857)	(0.000021028)
Ratified int. environmental agreements	-0.001926122***	-0.001362745***	-0.001378306***
	(0.000643978)	(0.000495132)	(0.000499482)
(leave-out) Mean collapse rate	-0.001344698	-0.002862213*	-0.002352139
	(0.001836080)	(0.001568566)	(0.001438039)
World price	-0.000000081*	-0.000000064*	-0.000000107***
	(0.000000048)	(0.000000039)	(0.000000040)
Time	0.000166056***	0.000160165***	0.000159647***
	(0.000027453)	(0.000023146)	(0.000023264)
Fully exploited$_t$	-0.000494416	0.000320898	0.000629377
	(0.000517882)	(0.000342332)	(0.000503637)
Fully exploited$_{t-1}$	-0.000035143		
	(0.000597907)		
Fully exploited$_{t-2}$	0.000318060		
	(0.000617936)		
Fully exploited$_{t-3}$	0.001201722**		
	(0.000565180)		
Fully exploited$_{t-4}$	-0.000669381		
	(0.000681162)		
Fully exploited$_{t-5}$	0.000334480		
	(0.000588786)		
Demersal		0.000442543	
		(0.000285939)	
Demersal × fully exploited		0.000401963	
		(0.000628660)	
World price × fully exploited			0.000000097
			(0.000000110)
Low price × fully exploited			0.000468143
			(0.001033936)
Medium price × fully exploited			-0.000666248
			(0.000857841)
High price × fully exploited			-0.001098025*
			(0.000609584)
Very high price × fully exploited			-0.000452453
			(0.000754201)
Observations	79,148	99,903	99,900

Country FE	YES	YES	YES
Species FE	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.2. The effects of ecological and economic conditions on PPR implementation for overfished fish stocks

Dependent variable *transition_into_PPRs*	(1)	(2)	(3)
GDP per capita	0.001447617***	0.001053551***	0.001178745***
	(0.000412500)	(0.000323850)	(0.000329599)
Population growth	-0.000353581	-0.000098019	-0.000067725
	(0.000346466)	(0.000250529)	(0.000254645)
Trade openness	-0.000032045***	-0.000022831***	-0.000023965***
	(0.000007766)	(0.000006438)	(0.000006391)
Polity index	-0.000009108	-0.000043107**	-0.000035035*
	(0.000023898)	(0.000020730)	(0.000020909)
Ratified int. environmental agreements	-0.001919953***	-0.001360903***	-0.001370406***
	(0.000644041)	(0.000495121)	(0.000497371)
(leave-out) Mean collapse rate	-0.001260885	-0.003094470**	-0.002542660*
	(0.001811521)	(0.001555941)	(0.001427987)
World price	-0.000000080*	-0.000000063	-0.000000068
	(0.000000049)	(0.000000039)	(0.000000045)
Time	0.000165257***	0.000159899***	0.000158122***
	(0.000027411)	(0.000023251)	(0.000023228)
Overfished_t	0.001080403*	0.000106145	-0.000556167
	(0.000570610)	(0.000442480)	(0.000620373)
Overfished_{t-1}	0.000560198		
	(0.000634748)		
Overfished_{t-2}	-0.000658468		
	(0.000610863)		
Overfished_{t-3}	-0.001203961**		
	(0.000594174)		
Overfished_{t-4}	0.000934985		
	(0.000757022)		
Overfished_{t-5}	-0.000539998		
	(0.000643619)		
Demersal		0.000421112	
		(0.000270559)	
Demersal × overfished		0.000665805	
		(0.000743677)	
World price × overfished			-0.000000062
			(0.000000109)
Low price × overfished			0.001653844
			(0.001116982)
Medium price × overfished			0.001792052
			(0.001092910)
High price × overfished			0.000233171
			(0.000761205)
Very high price × overfished			0.001009648
			(0.000914628)

Observations	79,148	99,903	99,900
Country FE	YES	YES	YES
Species FE	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.3. The effects of ecological and economic conditions on PPR implementation for collapsed fish stocks

Dependent variable *transition_into_PPRs*	(1)	(2)	(3)
GDP per capita	0.001351569***	0.001030480***	0.001141401***
	(0.000411402)	(0.000326588)	(0.000326913)
Population growth	-0.000339090	-0.000091651	-0.000063613
	(0.000346766)	(0.000250722)	(0.000254758)
Trade openness	-0.000032356***	-0.000023323***	-0.000024451***
	(0.000007803)	(0.000006463)	(0.000006413)
Polity index	-0.000006750	-0.000043410**	-0.000035110*
	(0.000023867)	(0.000020815)	(0.000020994)
Ratified int. environmental agreements	-0.001842179***	-0.001313699***	-0.001323387***
	(0.000644827)	(0.000492252)	(0.000495915)
(leave-out) Mean collapse rate	-0.000743626	-0.002334429	-0.001577373
	(0.001803681)	(0.001545891)	(0.001423253)
World price	-0.000000082*	-0.000000062	-0.000000065
	(0.000000048)	(0.000000039)	(0.000000046)
Time	0.000173708***	0.000166226***	0.000164770***
	(0.000027622)	(0.000023374)	(0.000023461)
$Collapsed_{t}$	-0.000347568	-0.001366752***	-0.001862498**
	(0.000623471)	(0.000426870)	(0.000940955)
$Collapsed_{t-1}$	-0.000134156		
	(0.000635078)		
$Collapsed_{t-2}$	-0.000984942*		
	(0.000576568)		
$Collapsed_{t-3}$	0.001176292		
	(0.000761493)		
$Collapsed_{t-4}$	-0.002063539***		
	(0.000697338)		
$Collapsed_{t-5}$	0.000334656		
	(0.000619271)		
Demersal		0.000570978**	
		(0.000271368)	
Demersal × collapsed		-0.000444972	
		(0.000637072)	
World price × collapsed			-0.000000088
			(0.000000078)
Low price × collapsed			0.000722743
			(0.001443692)
Medium price × collapsed			0.000919691
			(0.001147848)
High price × collapsed			0.000306894
			(0.000987691)
Very high price × collapsed			-0.000003142
			(0.001065494)

Observations	79,148	99,903	99,900
Country FE	YES	YES	YES
Species FE	YES	NO	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

C.2 Regressions with lagged values of the world price

Table C.4. The effect of lagged values of the price on PPR implementation for both dependent variables (ppr_implemented_cc & transition_into_PPRs) for fully exploited fish stocks

Dependent variable	*(1) ppr_implemented_cc*	*(2) transition_into_PPRs*
Fully exploited$_t$	0.00176963	0.000026576
	(0.00337278)	(0.000355292)
World price$_t$	-0.00000018	-0.000000067
	(0.00000041)	(0.000000062)
World price$_{t-1}$	-0.00000097**	-0.000000169
	(0.00000042)	(0.000000140)
World price$_{t-2}$	0.00000032	0.000000234
	(0.00000025)	(0.000000208)
World price$_{t-3}$	-0.00000010	-0.000000200
	(0.00000020)	(0.000000143)
World price$_{t-4}$	-0.00000017	0.000000257*
	(0.00000025)	(0.000000145)
World price$_{t-5}$	-0.00000156***	-0.000000126
	(0.00000048)	(0.000000147)
Observations	79,148	79,148
Country FE	YES	YES
Species FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.5. The effect of lagged values of the price on PPR implementation for both dependent variables (ppr_implemented_cc & transition_into_PPRs) for overfished fish stocks

Dependent variable	*(1) ppr_implemented_cc*	*(2) transition_into_PPRs*
Overfished_t	0.00837134*	0.000713299*
	(0.00470376)	(0.000420384)
World price_t	-0.00000018	-0.000000066
	(0.00000041)	(0.000000062)
World price_{t-1}	-0.00000099**	-0.000000171
	(0.00000042)	(0.000000140)
World price_{t-2}	0.00000031	0.000000233
	(0.00000025)	(0.000000209)
World price_{t-3}	-0.00000009	-0.000000200
	(0.00000020)	(0.000000143)
World price_{t-4}	-0.00000017	0.000000256*
	(0.00000025)	(0.000000145)
World price_{t-5}	-0.00000153***	-0.000000124
	(0.00000048)	(0.000000147)
Observations	79,148	79,148
Country FE	YES	YES
Species FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table C.6. The effect of lagged values of the price on PPR implementation for both dependent variables (ppr_implemented_cc & transition_into_PPRs) for collapsed fish stocks

Dependent variable	(1) *ppr_implemented_cc*	(2) *transition_into_PPRs*
Collapsed_t	-0.02532835***	-0.001334138***
	(0.00530887)	(0.000422559)
World price_t	-0.00000017	-0.000000066
	(0.00000041)	(0.000000062)
World price_{t-1}	-0.00000100**	-0.000000171
	(0.00000042)	(0.000000140)
World price_{t-2}	0.00000029	0.000000232
	(0.00000025)	(0.000000209)
World price_{t-3}	-0.00000011	-0.000000201
	(0.00000020)	(0.000000143)
World price_{t-4}	-0.00000015	0.000000258*
	(0.00000025)	(0.000000145)
World price_{t-5}	-0.00000153***	-0.000000124
	(0.00000048)	(0.000000147)
Observations	79,148	79,148
Country FE	YES	YES
Species FE	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1