ESSAYS ON INTERNATIONAL TRADE, ENVIRONMENTAL REGULATION AND RESOURCE MANAGEMENT

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1 Introduction

The last 70 years have witnessed a sustained and progressive global trend towards multilateral and bilateral trade liberalization. Each round of liberalization has been accompanied by a heated debate about the effect of trade on the environment and by fears of environmental degradation. The recent negotiations over the Transatlantic Trade and Investment Partnership (TTIP) are just one example which triggered protests by environmental NGOs, and fears that this trade agreement may undermine environmental standards.[1]

Despite environmentalist's opposition to free trade, the academic literature does not conclude that free trade is generally bad for the environment. The effect depends on environmental regulation and trade patterns. The literature following Grossman and Helpman (1993) and Antweiler et al. (2001) usually identifies three main channels via which trade changes pollution emissions from production. Firstly, trade affects the scale of production, leading to an increase in emissions. Secondly, specialization due to trade alters the composition of output. For countries which specialize in the production of polluting products, the composition effect raises pollution emissions. Countries which export clean products experience a reduction in pollution through the composition effect. Moreover, trade can reduce pollution through changes in the production technique. In Antweiler et al. (2001)'s framework,[2] this technique effect is the result of stricter environmental regulation in response to changes in income and changes in the price of the polluting product.[3] If countries implement stricter environmental regulations, firms abate more and the pollution intensity of production may

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[1] See e.g. Mathiesen (2014)

[2] Grossman and Helpman (1993) also highlights that trade can affect the production technique via a transfer of cleaner production technologies. However, the term technique effect usually refers to adjustments in production techniques as a results of policy changes.

[3] Trade is usually associated with an increase in income. Since environmental quality is considered a normal good, the optimal pollution tax tends to increases with income. Furhtermore, trade openness lead to an increase in the price of the polluting product of exporters of the latter. As consumers substitute away from the polluting product and demand more environmental quality, the optimal export tax increases further.

decline. This technique effect is beneficial for the environment. However, not all countries internalize the environmental externality through domestic pollution policy. If environmental policy is too lenient or is not adjusted in response to changes in income, the technique effect disappears.

Based on the exposition above, it is clear that trade can lead to an increase in emissions for some countries, particularly those countries which export pollution-intensive products and have lenient environmental policy. The potential negative effect of trade on the environment requires an adequate policy response. This is one of the topics discussed in this thesis.

The thesis consists of three substantive chapters which examine regulatory options for governments in countries which engage in international trade but fail to use domestic policies to internalize the distortions resulting from pollution or open access to renewable resources. Chapters 2 and 3 of the thesis study optimal trade policy in the context of production-generated pollution which generates a consumption externality. The theoretical model in Chapter 2 of the thesis shows that a country, which cannot implement the first best environmental policy, can use trade policy as a second-best instrument to reduce pollution. An empirical analysis in Chapter 3 investigates whether Chinese trade policy is motivated by environmental concerns.

The focus shifts from a consumption externality to a production externality in Chapter 4 of the thesis, which examines the effect of trade on the management of renewable resources. In the context of renewable resources, the externality results from the fact that an individual's harvest in one period reduces the stock and hence, the productivity of all harvesters in future periods (Copeland, 2011, p. 445). Chapter 4 of the thesis uses fisheries data in order to investigate empirically how international trade affects a government's decision to introduce property rights for fisheries.

The following sections provide a more detailed description of the chapters of this thesis and the methodologies used to study the respective research questions.

Trade policy as second-best environmental policy in China

The first part of this thesis studies the interaction between trade policy and pollution. Chapters 2 and 3 analyse situations in which the government cannot implement or enforce the first best environmental policy. In that case, trade policy can be a second-best instrument for countries which strive to reduce environmental problems.

The focus is on trade policy in China, a country which is faced with severe environmental degradation. China is the largest emitter of greenhouse gases globally (Steckel et al., 2011), and struggles with water pollution and severe water scarcity (Xie et al., 2009).

It is well known that the use of environmental regulation such as pollution taxes would be the first best way of internalizing these environmental externalities (see e.g. Markusen, 1975). However, China fails to enforce its comprehensive environmental law, mostly due to corruption. I explore whether and how China can use export taxes to reduce exports of pollution intensive products.

Chapter 2 of this thesis provides the theoretical framework for the analysis of trade policy as a second-best environmental policy in China. I extend the general equilibrium model by Copeland (1994) with multiple goods and multiple local pollutants to the case of a large country like China. In the model, a benevolent regulator tries to achieve welfare-maximizing pollution emissions and the welfare-maximizing international price level. In a first-best world, the regulator uses pollution taxes to internalize the environmental distortion and trade policy to achieve the optimal terms of trade. Yet, if environmental regulation is too lenient and cannot be changed, export taxes or import tariffs can be used as a second-best instrument to reduce pollution. Chapter 2 shows that the second-best export tax is higher for goods which are more pollution-intensive as long as pollution regulation is more lenient than in the first best. The intuition behind this result is simple: The production of pollution-intensive goods which are subject to an export tax declines when the export tax is increased. As a consequence, resources shift into less damaging activities, thus reducing overall pollution.

The results from the theoretical model in Chapter 2 guide the empirical analysis of China's trade policy in Chapter 3. Since 2007, China has introduced export taxes and reduced export value-added tax (VAT) rebates for a range of products. According to China's National Development and Reform Commission, the VAT rebate adjustments aim at controlling “exports of energy-intensive, pollution-intensive and resource-intensive products, so as to formulate an import and export structure favourable to promote a cleaner and optimal energy mix” (NDRC, 2007, p. 31). The empirical analysis investigates, whether, in practice, Chinese trade policy reflects environmental motives. To the best of my knowledge, this is the first empirical study of trade policy as a second-best environmental policy.

It is not obvious that VAT rebate and export tax adjustments are driven by environmental concerns. Other potential motives include an attempt to manipulate the terms of trade in China's favour, a desire to attract downstream producers to China or lobbying pressure by different industries.

The theoretical model presented in Chapter 2 of the thesis shows that a government sets higher export taxes for more polluting products if it uses trade policy as a second-best environmental policy. The empirical analysis, thus, investigates whether Chinese export taxes increase in a product's pollution intensity even after controlling for other motives to manipulate trade policy. I use data on Chinese export VAT rebates, export taxes and import tariffs which was merged with information on industry-level pollution intensities. The analysis considers all pollutants for which the Chinese government has specified emission reduction targets in its Five-Year-Plans. These include waste water, chemical oxygen demand (COD), ammonium nitrogen, soot, SO_2, solid waste and energy use.

The results lend support to the Chinese authorities' claim that the export VAT rebate adjustments are driven by environmental concerns. The VAT rebate rates are set in a way which discourages exports of water pollution intensive and energy intensive and products. Moreover, the conservation of natural resources such as minerals, metals, wood products and precious stones seems to be a key determinant of China's VAT rebate rates.

However, there is little evidence that the export tax is used as a secondary instrument to reduce pollution or conserve natural resources. The export tax seems to be motivated by an attempt to protect downstream producers in China, since the export taxes are higher for primary products.

International trade and fisheries management

The second part of this thesis also studies a government's decision to protect the environment in the context of international trade. However, the focus is now on the effect of trade on the management of a renewable resource.

To be precise, Chapter 4 investigates the link between trade and the introduction of catch share programs for fisheries. Those programs allocate secure privileges to individual entities. They can either be quota-based or area-based. Area-based programs are also known as Territorial Use Rights for Fishing programs (TURFs) and allocate the privilege to fish in specific areas to groups or individuals. Quota based catch share programs allocate the right to fish a certain percentage of a total allowable catch to individuals, groups or vessels.

Research on the effect of trade on the introduction of catch share programs is not only of academic interest but of high policy relevance. Fisheries products have become a highly traded commodity. According to FAO (2008) nearly 40 percent of the global fish production is traded. The total value of trade in fisheries products increased from 8 billion US$ in 1976 to 130 billion US$ in 2011.[4]

At the same time fisheries collapse is a widespread phenomenon. According to Worm et al. (2006), about 27% of the world's fisheries were collapsed[5] by 2003 and the percentage of collapsed fisheries is increasing. It is obvious that the world's fisheries need to be managed in a more sustainable way. Catch share programs have turned out to be successful instruments in avoiding fisheries collapse (Costello et al., 2008). Hence, a study of the factors which motivate a government to introduce catch share programs can give important insights for the sustainability of the world's oceans.

The theoretical literature on trade in renewable resources has pointed out that trade can lead to overharvesting and welfare losses for resource exporters in the absence of well-defined property rights for the resource (Chichilnisky, 1994; Brander and Taylor, 1997b,a). Yet, if a country fully internalizes the production externality, trade is always welfare improving (Copeland, 2011, p. 447). In other words, the effect of trade on harvesting of renewable resources and welfare depends on property rights or the institutional framework. This is confirmed by empirical work by Ferreira (2004); Deacon (1994); Bohn and Deacon (2000) and in the survey by Barbier and Burgess (2001).

All of the above-mentioned papers treat institutions as exogenous. However, from a theoretical point of view, trade can alter institutions and the management of renewable resources through changes in the relative price of the resource. The literature proposes several mechanisms via which an exogenous change in the price can affect resource management. In Sethi and Somanathan (1996)'s evolutionary game-theoretic framework, harvesting restrictions are based on social norms. Sethi and Somanathan (1996) show that an exogenous increase in the price, which could be caused by opening up to trade, can lead to the collapse of social norms and resource management. Barbier et al. (2005) analyse the effect of trade openness on resource management in an environment with a corrupt regulator. As the price for the resource good increases, firms have higher benefits from bribing

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[4] Author's calculations based on data by the FAO.

[5] Worm et al. (2006) define a fishery as collapsed in year t if the catch in that year is less than 10 percent of the maximum catch since 1950.

the government for larger harvesting quotas. Opening up to trade can thus increase resource extraction and deteriorate management. Another stream of the literature holds that a higher price could lead to the introduction of property rights or harvesting restrictions (Demsetz, 1967; Copeland and Taylor, 2009) or to the enforcement of existing property rights (Hotte et al., 2000; Tajibaeva, 2012).

With such conflicting theoretical predictions, empirical evidence is necessary to shed light on the relationship between trade and the management of a renewable resource. To the best of my knowledge, there is no existing empirical analysis on the link between international trade and the management of a renewable resource. The analysis in Chapter 4 of this thesis tries to fill this gap using fisheries data.

In order to be able to investigate the effect of trade on fisheries management, I assembled a unique dataset which contains information on the adoption of catch share programs, the price of fish, trade in fisheries products as well as a range of country and fisheries characteristics. The dataset is very detailed and allows me to study a government's decision to introduce management for a particular fish species at the country-species level.

The analysis focuses on the factors which motivate a government's initial decision to introduce catch share programs. This is best modelled using survival analysis. I observe every fishery until it has adopted a catch share program. After the introduction of a catch share program, the fishery disappears from the dataset. This approach guarantees that long-term adjustments in the fishery due to the introduction of catch share programs do not affect the empirical findings.

The results show a robust negative relationship between the price and the introduction of catch share programs. However, I also find that the lower-priced species which adopt catch share programs are caught in significantly larger quantities and that the value of landings is significantly higher in fisheries which introduce catch share programs. Part of this value is generated in export markets and the results reveals that the export value is significantly positively correlated with the introduction of catch share programs.

However, the data do not suggest that openness to trade, measured as the percentage of domestic catch which is traded, is a significant factor in the decision to introduce catch share programs. Moreover, the likelihood that a government introduced catch share programs does not differ significantly between fisheries which export their products and those which do not.

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

The findings of this thesis and their implications for future research are summarised in Chapter 5. Particularly the results on trade and fisheries management should trigger further research. Chapter 4 finds that lower-valued species are more likely to be managed. Potential explanations for this finding include a collapse of social norms, lobbying against catch share programs or cost differences. Due to a lack of data on lobbying efforts and fishing cost, this cannot be investigated in this thesis. Future research should explore the mechanisms which explain a negative relationship between the price and the introduction of catch share programs.

Moreover, the empirical results from Chapter 4 do not allow us to conclude that trade is either good or bad for the management of renewable resources. The analysis is of exploratory nature and uses several measures to capture openness to international trade. The different measures point in different directions. Future research should try to find more conclusive results and explain the channels via which trade affects the management of renewable resources.

In this context, fisheries are not the only resource that should be investigated. It would be insightful to know whether similar patterns apply to other renewable resources such as forests.

2 Trade policy as second-best environmental policy for a large country

Abstract

This chapter investigates the use of trade policy as a second-best environmental policy option for a large country which produces many goods and generates multiple local pollutants. We solve for the welfare maximizing trade policy vector which is chosen by a benevolent regulator who cannot adjust pollution taxes. The model shows that the second-best export tax increases in a product's pollution intensity as long as environmental regulation is too lenient to internalize the externality resulting for pollution.

2.1 Introduction

In recent years, China has introduced export taxes and reduced export value-added tax (VAT) rebates for a range of products.[1] According to China's National Development and Reform Commission, the VAT rebate adjustments aim at controlling "exports of energy-intensive, pollution-intensive and resource-intensive products, so as to formulate an import and export structure favourable to promote a cleaner and optimal energy mix" (NDRC, 2007, p. 31).

From a theoretical point of view, the decision to use trade policy as an instrument to reduce pollution can only be a second best option. It is well known that a pollution tax is the first best way of achieving a desired domestic pollution outcome both for small and large countries (see e.g. Copeland, 2011). If the government is constrained in its use of pollution taxes to internalize the environmental distortion, a welfare-maximizing regulator can use trade barriers as second-best policy instruments. This has been demonstrated by Copeland (1994) for a small country which produces many goods and by Markusen (1975) for the case of a large country which produces one polluting good and one clean good.

This chapter of the thesis investigates the use of trade policy as a second-best environmental policy option for a large country which produces many goods and generates multiple types of local pollution but cannot adjust the pollution tax. We use a general equilibrium model of a large open economy which is subject to local pollution and a trade distortion. The model is an extension of a model by Copeland (1994), which analyses the relationship between trade and environmental policy for an open economy with many goods and many pollutants. While Copeland (1994) only considers a small country, this chapter of the thesis analyses the relationship between trade and pollution policy in a large country which can influence the terms of trade.

In the model, a benevolent regulator tries to achieve welfare maximizing pollution emissions and the welfare maximizing international price level. Hence, pollution and the terms of trade are the targets of the policy. In order to achieve the first-best combination of pollution and terms-of-trade, the regulator needs to have two policy instruments at hand. In this chapter,

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[1] The reduction of export VAT rebates has a similar effect as an increase in the export tax in the sense that lower VAT rebates reduce exports (see Feldstein and Krugman (1990) for a theoretical foundation and Chao et al. (2001); Chen et al. (2006); Chao et al. (2006); Chandra and Long (2013) for empirical evidence).

these instruments are trade policy variables (i.e. import tariffs or subsidies or export taxes or subsidies) as well as pollution taxes. Our analysis considers unilateral changes in trade and environmental policy. The rest of the world is assumed to consist of many countries which do not respond to the large country's policy reform. The model shows that, when both trade and environmental policy can be chosen optimally, trade policy variables are used to manipulate the terms of trade and pollution taxes are set such that the environmental distortion is internalized. This is the first-best combination of policy instruments.

As opposed to Copeland (1994), we explicitly solve for the second-best export tax, which is chosen if the government is constrained in setting optimal pollution taxes. This allows us to investigate how a large country which produces multiple goods should design a second-best export tax. Moreover, we provide comparative statics. The resulting information on the variation of second-best export taxes across products with varying pollution intensities guides our empirical analysis in the next chapter.

The second-best tariff or export tax takes account of both the terms-of-trade motive and the need to internalize the environmental distortion. We show that the second-best export tax is higher for goods which are more pollution-intensive as long as pollution regulation is more lenient than in the first best. The intuition behind this result is as follows: The production of pollution intensive goods which are subject to an export tax declines when the export tax is increased. As a consequence, resources shift into less damaging activities, thus reducing overall pollution.

Our analysis also demonstrates that environmental concerns are not the only potential driver behind the implementation of export taxes in a large country. Governments in large countries also set export taxes in order to manipulate their terms of trade. The formula for the second-best export tax derived in this chapter shows that the terms of trade motive and the environmental motive to introduce an export tax are additive and there is no interaction between the terms of trade motive and the environmental motive.

This chapter is structured as follows. Section 2.2 reviews the related theoretical literature. The model set-up is explained in Section 2.3. Section 2.4 presents the first best policy combination followed by an explanation of the welfare effects of small changes in pollution taxes and trade tariffs in Section 2.5. Section 2.6 derives the second-best tariff which is chosen by a regulator who can only reform trade policy but not pollution policy. A simplified formula for the second-best export tax is explained in Section 2.7. This section also derives comparative statics and shows that he second-best tariff declines in a product's pollution intensity. Section 2.8 argues that the model also applies to export taxes and shows the formula for the second-best export tax and Section 2.9 explains the policy implications of the formula for a country which wants to implement second-best export taxes. Finally, Section 2.10 concludes.

2.2 Related literature

The large open economy described in our model is subject to local pollution and a trade distortion. The model is an extension of a model by Copeland (1994), which analyses the relationship between trade and environmental policy for an open economy with many goods and many pollutants. While Copeland (1994) only considers a small country, this chapter of the thesis analyzes the relationship between trade and pollution policy in a large country which can influence the terms of trade. Even though our model set-up is similar to Copeland (1994), there is a difference in the focus of the analysis. Copeland (1994) examines welfare-improving gradual reforms whereas the goal of our analysis is the derivation of a the second-best tariff and a second-best export tax. The second-best trade policy instrument maximizes welfare if the government cannot internalize environmental distortions using a domestic pollution tax.

Trade policy is set unilaterally in our analysis and we assume that the rest of the world does not respond to these policy choices. In this sense, our work can also be considered an extension of the model by Turunen-Red and Woodland (2002) who examine welfare effects of unilateral trade and environmental policy reforms for a small country. Holding environmental policy constant, Turunen-Red and Woodland (2002) show that a gradual movement towards the second-best tariff is welfare improving, given a certain correlation condition is satisfied. This correlation condition holds if protection is high for industries which are highly polluting but subject to a low environmental levy, given that an increase in the price leads to an increase in pollution for a large number of industries.

Both Copeland (1994) and Turunen-Red and Woodland (2002) model small open economies. The main focus of our analysis is a trade policy reform for a large country in which both trade and environmental policy affect the terms of trade. Hence, we extend Copeland (1994)'s model with many goods and many pollutants to the large country case and explicitly derive the second-best tariff.

First and second-best trade policies for a large country in the presence of environmental distortions have been considered by Markusen (1975). In his model, two large open economies produce two goods. One good generates pollution during the production process. Pollution affects the consumer's utility but does not impact on productivity. The focus of Markusen (1975)'s analysis is on international pollution but the paper nests purely local pollution as a special case. Both countries have a regulator who sets welfare-maximizing trade tariffs, consumption taxes or production taxes. The production tax in his paper would be the similar to the pollution tax in our analysis. Just as in our model, Markusen (1975) assumes that policy choices are unilateral and that the foreign country does not react to the domestic policy choice.

Markusen (1975) looks at the first-best policy if both the production tax and trade policy can be set optimally. If the good is imported and if pollution is local, the first-best tariff is an inverse function of the foreign elasticity of export supply, which represents the terms of trade motive. The same result can be found in Copeland (2011) in a framework that only applies to local pollution. In the second part of his paper, Markusen (1975) analyses second-best policy choices in an environment in which the regulator can only adjust the trade tariff but not the production tax. If pollution is local, the second-best tariff is tends to be lower than the first-best tariff.

Markusen (1975)'s findings for the special case of local pollution are in line with our findings for the special case in which the economy only consists of a polluting and a clean good. However, we are interested in a model with many goods which we can rank according to their pollution intensity. This allows us to derive comparative statics which can guide an empirical analysis in the next chapter. Hence, we need a large country framework with many goods and pollutants. Moreover, a framework with many goods allows us to show how a second-best export tax should be designed in a large country which produces many goods which generate pollution during the production process.

An analysis of the interaction between trade and environmental policy for a large country which produces many polluting goods is provided by Turunen-Red and Woodland (2004). Their theoretical framework applies to both local and global pollution. However, the focus of Turunen-Red and Woodland (2004)'s analysis is very different from ours. Turunen-Red and

Woodland (2004) are interested in the conditions under which multilateral reforms of environmental policy generate welfare improvements. In contrast to Turunen-Red and Woodland (2004), we focus on unilateral reforms of trade rather than environmental policy. Multilateral welfare effects are not taken into consideration in our analysis.

2.3 The model

A perfectly competitive large open economy, which will be referred to as "China" in this chapter, produces or consumes $N_g + 1$ goods. Good 0 is the numeraire. Production and consumption of good 0 are denoted by y_0 and c_0. The vectors y and c represent production and consumption of all other N_g goods.

Production of all non-numeraire goods causes local pollution. Local pollution means that pollution does not cross the border and the rest of the world is unaffected by domestic pollution. The model considers N_p different pollutants and pollution emissions are represented by the vector z. Pollution reduces the consumer's utility but does not affect the productivity in other sectors. Firms face pollution taxes s per unit of pollution for each of the pollutants.

The government levies tariffs for all non-numeraire goods. These tariffs are represented by the vector t. The world market and domestic price vectors for the non-numeraire goods are denoted by p and $q = p + t$. There is no tariff for the numeraire. Hence, both the domestic and the world market price for the numeraire equal 1.

The representative consumer's utility is a function of consumption and of the public bad pollution $u(c_0, c, z)$. We assume that the utility function is well-behaved in the sense that it is continuous, locally unsatiated and strictly convex. The utility can be represented by the expenditure function $E(1, q, z, u)$. The expenditure function is concave and non-decreasing in q and increasing in z and u. By Shephard's lemma, $E_q = \partial E / \partial q'$ is the compensated demand vector. $E_z = \partial E / \partial z'$ represents the marginal willingness to pay for a one unit reduction in pollution. In other words, E_z is the marginal damage caused by pollution.

Following Copeland (1994), the production side of the economy is represented by the aggregate revenue or GNP function. Firms maximize their profits, taking the pollution tax s and the prices q as given. The profit maximizing behaviour of the individual firms also maximizes GNP less the pollution tax. Hence, the private sector implicitly solves the problem

$$G(1,q,s,v) = \max_{y,z}\{y_0 + q'y - s'z \quad s.t. \ (y_0,y,z) \in T(v)\} \tag{2.1}$$

where the prime ($'$) denotes a transpose. v is the endowment of the economy and $T(v)$ is the technology set. The constraint ensures that output is in the technology set. Based on the envelope theorem, $y = G_q = \partial G/\partial q$ and $z = -G_s = -\partial G/\partial s$.

2.3.1 Goods market equilibrium

The world in this model consists of China and the rest of the world. China is modelled as a large country and changes in Chinese import (or export) quantities can affect the world market price. Adjustments in Chinese trade policy which affect import demand (or export supply) can therefore affect the terms of trade. An increase in the tariff of a product raises the domestic price and reduces the demand for imports of this product. This reduction in demand can result in a lower world market price for the product.

The benevolent Chinese regulator unilaterally chooses the optimal combination of policy instruments in response to local pollution and in order to manipulate the terms of trade. Our analysis considers unilateral changes in trade and environmental policy. We assume that the rest of the world does not to adjust its trade and environmental policy in reaction to changes in Chinese trade and environmental policy. This assumption is not unreasonable if the rest of the world consists of many small countries which do not coordinate their policy.

Since the analysis focuses on a large country, which can affect the world price, it is necessary to model the international goods market.[2] The goods market equilibrium is characterized by the following equation

$$-E_q(1,q,z,u) + G_q(1,q,s,v) - E_p^*(1,p) + G_p^*(1,p) = 0_N \tag{2.2}$$

where E^* and G^* denote foreign compensated demand and foreign production, respectively.[3] Since we abstract from the foreign policy process, foreign production and consumption are functions of the world market price, but not of the Chinese policy variables.

Why does Equation 2.2 allow us to pin down the international price level?

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[2] The small open economy is a price taker on the world market. Therefore, papers like Copeland (1994) do not need to model the international goods market equilibrium.

[3] This approach is similar to Vlassis (2013).

Holding tariffs and pollution taxes constant, the model assumes that both consumption and production in each of the economies adjust optimally to changes in the world market price. The goods market equilibrium makes sure that the price adjusts in such a way that global production of a good equals global consumption. This is more obvious if we rewrite the goods market equilibrium condition as

$$S(1,p,t,s,v) = G_q(1,q,s,v)+G_p^*(1,p) = E_q(1,q,z,u)+E_p^*(1,p) = D(1,p,t,s,v)$$

where the left hand side denotes global sales $S(p)$ as a function of the world market price and the right hand side denotes global purchases $D(p)$ as a function of the world market price. Due to Walras' law, the equation for the numeraire can be dropped when we define the goods market equilibrium.[4]

2.3.2 Equilibrium conditions

Assuming that the pollution taxes are rebated to the consumer, the equilibrium in the economy is characterized by the following four equations

$$E(1,q,z,u) = G(1,q,s,v) + s'z + t'M \tag{2.3}$$

$$M = E_q(1,q,z,u) - G_q(1,q,s,v) \tag{2.4}$$

$$z = -G_s \tag{2.5}$$

$$-E_q(1,q,z,u) + G_q(1,q,s,v) - E_p^*(1,p) + G_p^*(1,p) = 0_N \tag{2.6}$$

The variable M in Equations 2.3 and 2.4 represents the net import vector

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[4] According to Walras' law the remaining market must clear, if all markets but one clear. Walras' law is based on the the notion that total sales equal total purchases. This is true if our goods market equilibrium holds true as can be seen in Equation 2.3.1. The goods market equilibrium condition can be multiplied by the transpose of a column price vector to state that the value of total production equals the value of total consumption.

$$p'S(1,p,t,z,v) = p'D(1,p,t,z,v)$$

This can also be written as

$$\sum_{i=1}^{N} p_i S_i(p_i) = \sum_{i=1}^{N} p_i D_i(p_i)$$

If this equation holds true, the goods market for the numeraire must also be in equilibrium. Noting that the price for the numeraire is one, this can be expressed as

$$\sum_{i=1}^{N} p_i S_i(p_i) + S_0 = \sum_{i=1}^{N} p_i D_i(p_i) + D_0.$$

which equals compensated demand (E_q) minus output (G_q). Equation 2.5 pins down the equilibrium pollution level in the economy. Equation 2.3 is like a budget constraint for the economy. It states that consumer expenditure equals GNP plus the rebated pollution tax and tariff income. If the economy-wide budget constraint is satisfied, trade is balanced. Equation 2.3 does not allow for a trade deficit or surplus. Equation 2.6 repeats the goods market equilibrium which was explained in Section 2.3.1.

2.4 First-best policy

For the analysis it is important to note that the regulator's ultimate goal is welfare maximization. Welfare depends on pollution and on the international price level. Hence, those two variables are the target of the regulator's policy. Since the regulator cannot directly choose the international price level and pollution, he uses trade policy and environmental policy in order to achieve these targets.

In this section, we derive the first-best policy combination by maximizing welfare over the policy targets, i.e. the international price level and pollution. This will give us the first-best environmental and trade policies that the welfare-maximizing regulator chooses if he is not constrained in the way he sets the policy instruments.

We take the total differential of Equation 2.3 and assume that the technology set remains unchanged ($dv = 0$). Since China is modelled as a large country, the world market price is not exogenous and $dq = dp + dt$.[5]

$$E_u du + E_q'(dp + dt) + E_z dz = G_q'(dp + dt) + G_s' ds + z' ds + s' dz + t' dM + M' dt \tag{2.7}$$

Using (2.4) and (2.5), $G_s' ds = -z' ds$ and $E_q - G_q = M$, the total differential simplifies to

$$E_u du = -(E_z - s)' dz + t' dM - M' dp. \tag{2.8}$$

With E_u being the inverse of the marginal utility of income, $E_u du$ can be considered a measure for a change in welfare. The terms of trade effect is captured by $M' dp$.

Defining exports of the rest of the world as $X^* = -E_p^*(1, p) + G_p^*(1, p)$, the goods market equilibrium equation 2.2 can be summarized as $M(p, t, s) = X^*(p)$. From this equation, we obtain $dM = \frac{\partial X}{\partial p'} dp = X_p^* dp$.[6] Equation 2.8

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[5] In the case of a small country, Chinese policy cannot affect the world price and $dq = dt$.

[6] Here I follow Copeland (2011). Note that the same result can be obtained if we solve

can then be written as

$$E_u du = -(E_z - s)'dz + t'X_p^* dp - X^{*'} dp \tag{2.9}$$

Setting $du/dz = 0$, Equation 2.9 allows us to derive the welfare maximizing pollution tax

$$E_z = s. \tag{2.10}$$

Equation 2.10 shows that the first best pollution tax equals marginal damage. This guarantees that the price of an additional unit of pollution, which is represented by the pollution tax, equals the representative consumer's willingness to pay for a reduction in pollution by one unit.

The welfare maximizing tariff can be obtained from Equation 2.9 if $du/dp = 0$

$$t' = X^{*'}(X_p^*)^{-1}. \tag{2.11}$$

Holding everything else constant, the optimal tariff for product i is closer to zero the larger X_{ip_i}, or the more responsive foreign exports of good i are to a change in the domestic price of good i.[7] For a small country, the price elasticity of the rest of the world's export supply is infinite. Hence, the optimal tariff for a small country is zero (ignoring cross-price elasticities). In other words, Equation 2.11 nests the optimal tariff for a small country as a special case. The large country, however, sets a positive tariff. The tariff raises the cost of a product on the domestic market. Due to the lower import demand, the world market price falls. The tariff, thus, allows China to influence the terms of trade.

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for dM as a function of changes in pollution policy ds and changes in trade policy dt.

[7] We can write $t' = X^{*'}|X_p^*|adj(X_p^*)$, where $|X_p^*|$ is the determinant of the matrix X_p^* and $adj(X_p^*)$ is the adjugate of matrix X_p^*. The tariff for product i only depends on X_{ip_i} through the determinant $|X_p^*|$. The determinant $|X_p^*|$ increases, in absolute terms, in X_{ip_i}. Hence, the optimal tariff declines, in absolute terms, in X_{ip_i}.

If we assume that $\frac{\partial X_j}{\partial p_i} = 0 \; \forall \; i \neq j$, the optimal tariff simplifies to the well-known formula for the optimal tariff in partial equilibrium models

$$\tau_i = \frac{t_i}{p_i} = \frac{X_i^*}{X_{ip_i}^* p_i} = \frac{1}{\epsilon_{X^* p_i}}$$

where τ_i is a multiplicative tariff and $\epsilon_{X_p^*}$ is the elasticity of foreign export supply (see e.g. the survey by Copeland, 2011).

2.5 Welfare effect of small changes in pollution taxes and tariffs

Equation 2.9 gives us the change in welfare caused by a change in emissions or imports. These are the targets of our policy. We can also express the welfare changes as a function of the policy instruments. In order to achieve this, we totally differentiate Equation 2.4 and Equation 2.5 to get

$$dM = (E_{qq} - G_{qq})d(p+t) + E_{qz}dz + E_{qu}du - G_{qs}ds. \tag{2.12}$$

$$dz = -(G_{sq}d(p+t) + G_{ss}ds) \tag{2.13}$$

The matrix E_{qq} is the matrix of price derivatives of the compensated demand function $E_q(1, q, z, u)$. With continuous, locally unsatiated and quasiconvex preferences, the matrix E_{qq} is symmetric and negative semidefinite (see e.g. Mas-Colell et al., 1995, p. 70-71). The diagonal elements of the matrix are nonpositive. In other words, the compensated own-price elasticities $E_{q_iq_i} \leq 0$. The matrix G_{qq} contains the price derivatives of output. The matrix is symmetric and positive semidefinite.

Equation 2.13 shows that both the tariff and the pollution policy can be used to achieve a reduction in pollution.

Throughout this chapter, we assume that income effects attach to the numeraire. In other words, we assume that $E_{qu} = 0_N$.[8] Using this assumption and substituting Equations 2.12 and 2.13 into Equation 2.8 yields

$$\begin{aligned} E_u du = {} & \left[(E_z - s)'G_{sq} + t'(E_{qq} - G_{qq} - E_{qz}G_{sq})\right] d(p+t) \\ & - M'dp \\ & + (E_z - s)'G_{ss}ds - t'(E_{qz}G_{ss} + G_{qs})ds \\ & + t'E_{qu}du. \end{aligned}$$

Defining the matrix $H_{qq} = G_{qq} - E_{qq}$, which captures the response of

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[8] This assumption is not necessary at this stage. However, we use the assumption later on to achieve tractability when we use the total differential of the goods market equilibrium condition in equation 2.15. Note that if we did not make this assumption, we could define the the marginal propensity to consume $m = E_{qu}/E_u$ and Equation 2.14 could be written as

$$E_u du(1 - t'm) = [\delta_z G_{sq} - t'H_{qq}]d(p+t) - M'dp + [\delta_z G_{ss} - t'G_{qs}]ds$$

Stability requires that the tariff multiplier $1 - t'm > 0$ (Neary and Ruane, 1998).

domestic exports to a change in the domestic price, the welfare effects of small policy changes can be written as

$$E_u du = [\delta_z G_{sq} - t' H_{qq}] d(p+t) - M' dp + [\delta_z G_{ss} - t' G_{qs}] ds \qquad (2.14)$$

where $\delta_z = E_z' - t' E_{qz} - s'$ is the gap between the marginal damage caused by pollution $E_z' - t' E_{qz}$ and pollution tax s. Marginal damage consists of the direct effect of pollution E_z and the indirect effect $t' E_{qz}$. The direct effect represents the consumer's marginal willingness to pay for a one unit reduction in pollution. The indirect effect of pollution on the consumer, $t' E_{qz}$, works through the trade distortion. To understand the intuition behind the indirect effect, think of a good which is protected by a tariff. Imports of the protected good will be low compared to a situation without a tariff. If this good is a complement to environmental quality, like a picnic basket, then the compensated demand for that good falls as pollution increases and $E_{qz} < 0$. As a results, imports decline even further due to pollution, thus exacerbating the trade distortion.

Using the goods market equilibrium condition, we can solve for the change in the international price vector as a function of changes in trade policy and pollution taxes. Based on Equation 2.13, the total differential of the goods market equilibrium condition is given by

$$(H_{qq} + H^*_{pp} + E_{qz} G_{sq}) dp + (H_{qq} + E_{qz} G_{sq}) dt + (G_{qs} + E_{qz} G_{ss}) ds = 0 \quad (2.15)$$

where $H_{qq} = G_{qq} - E_{qq}$ and $H^*_{pp} = G^*_{pp} - E^*_{pp}$ are the response for domestic exports and foreign exports to changes in the domestic and world market price, respectively. Since we assume that income effects attach to the numeraire, $E_{qu} = 0_N$.

We define

$$\Lambda = -H_{qq} - H^*_{pp} - E_{qz} G_{sq} \qquad (2.16)$$

and assume that Λ is of full rank and hence invertible. The variable Λ captures the complete effect of changes in the world market price on production and consumption including the effect of changes in pollution on the consumption choice: The matrices H_{qq} and H^*_{pp} capture the changes in net exports in China and in the rest of the world, respectively, and, thus, capture the direct effect of changes in the world market price on consumption and production. The matrix $G_{sq} = -\frac{\partial z}{\partial q}$ represents a change in environmental quality which results from changes in the world market price as the structure of production is altered. This change in pollution, in turn, affects the consumption decision, as represented by the matrix E_{qz}.

Using the definition of Λ, we solve for the change in prices as a function of changes in the pollution tax and the tariff

$$dp = \Lambda^{-1}[(G_{qs} + E_{qz}G_{ss})ds + (H_{qq} + E_{qz}G_{sq})dt] \tag{2.17}$$

In this equation $G_{qs} + E_{qz}G_{ss}$ measures the impact of a change in the pollution tax on domestic production, G_{qs}, and consumption, $-E_{qz}G_{ss}$. The effect of the pollution tax on consumption is indirect and works through changes in the environmental quality caused by the pollution tax, $G_{ss} = -\frac{\partial z}{\partial s}$, which in turn affect the consumption decision E_{qz}. The effect of a change in the pollution tax on domestic production and consumption is considered relative to the effect of a change in the price level on global production and consumption which is captured by Λ. The term Λ^{-1} appears in Equation 2.17 since the change in the international price level offsets some of the effects of the pollution tax. This can be illustrated easily using the two-goods case as an example. In the two good case, one good pollutes and the numeraire does not pollute. An increase in the pollution tax leads to a reduction in production of the polluting good and to a decline in pollution. If the non-numeraire good is a substitute for pollution, domestic consumption increases. An increase in consumption and a decline in production is equivalent to an increase in net imports. For a large country, this increase in net imports must be accompanied by an increase in the international price for the polluting good. The rising world market price, however, stimulates production of the non-numeraire good and thus offsets some of the effects of the pollution tax. Compared to a small country for which the international price is fixed, the increase in the pollution tax has to be larger in order to achieve the same reduction in pollution.

A similar reasoning applies to the change in the tariff. $H_{qq} + E_{qz}G_{sq}$ represents the effect of a change in the tariff on domestic consumption and production. This effect is considered relative to the effect of a change in the world market price on domestic production and consumption.

Equation 2.17 shows that the international price level can be manipulated using either the tariff or the pollution tax.

Substituting Equation 2.17 into Equation 2.14 yields

$$\begin{aligned}E_u du &= [\delta_z G_{sq} - t' H_{qq}]dt + [\delta_z G_{ss} - t' G_{qs}]ds \\ &\quad + (\delta_z G_{sq} - t' H_{qq} - M')\Lambda^{-1}[(G_{qs} + E_{qz} G_{ss})ds + (H_{qq} + E_{qz} G_{sq})dt]\end{aligned}$$

Rewriting this equation and using the definition of Λ from Equation 2.16, this can be simplified to

$$\begin{aligned}E_u du &= -[\delta_z G_{sq} - t' H_{qq}]\Lambda^{-1} H^*_{pp} dt \\ &\quad - M'\Lambda^{-1}(H_{qq} + E_{qz} G_{sq})dt \\ &\quad + (\delta_z G_{ss} - t' G_{qs})ds + (\delta_z G_{sq} - t' H_{qq})\Lambda^{-1}(G_{qs} + E_{qz} G_{ss})ds \\ &\quad - M'\Lambda^{-1}(G_{qs} + E_{qz} G_{ss})ds\end{aligned} \tag{2.18}$$

An increase in the tariff has three effects on welfare. Firstly, it has a direct effect via the substitution matrix H_{qq} multiplied by the initial tariff level. Secondly, there is an indirect effect via changes in pollution. The welfare consequences of the indirect effect are measured by $\delta_z G_{sq}$, where δ_z denotes the gap between the pollution tax and the total disutility that consumers derive from another unit of pollution. Thirdly, it has an impact on the international price level. Imagine a tariff is introduced on good 1. This leads to an increase in domestic supply and a reduction in domestic demand for good 1, leading to a decline in domestic imports. As a consequence of the decline in domestic imports, the world market price for the good must fall if China is a large importer, offsetting part of the effect of a tariff. This own-price effect as well as the cross-price effects are captured by $\Lambda^{-1} H^*_{pp}$, where Λ measures the entire effect of a change in the international price on global consumption and production and H^*_{pp} measures the response of foreign exports to changes in the world market price. The expression $-M'\Lambda^{-1}(H_{qq} + E_{qz} G_{sq})dt$ captures the change in the value of the initial import bundle resulting from a change in the international price level caused by a change in the tariff. It is equivalent to the terms of trade effect Mdp if the pollution tax is unaltered.

In the same vein, changes in the pollution tax have a direct welfare effect through changes in pollution emissions and an indirect effect on the trade distortion. Moreover, changes in the pollution tax affect welfare through changes in the terms of trade. This is represented by the expression $\Lambda^{-1}(G_{qs} + E_{qz} G_{ss})ds$. The matrices G_{sq} and $E_{qz} G_{ss}$ describe changes in output and consumption, which are caused by changes in the pollution tax. This change in net exports causes changes in the international price level. Hence, the production and consumption effects caused by changes in pollution are considered relative to the effect of a change in the international price level on production and consumption, Λ. The change in the price level affects welfare via the trade distortion ($t'H_{qq}$) and via pollution ($\delta_z G_{sq}$). The scalar $M'\Lambda^{-1}(G_{qs} + E_{qz}G_{ss})ds$ denotes the change in the value of the initial import bundle caused by a change in the pollution tax, holding the tariff constant. It is equivalent to $M'dp$ in a situation in which the tariff is unaltered.

With more than one distortion, a reduction of any one distortion may raise or reduce welfare because of substitution effects. Assume that the pollution tax for one pollutant is raised. Emissions of this particular pollutant are likely to fall. However, as a consequence of substitution effects, emissions of another pollutant may rise. This could lead to a reduction in welfare. In the same way, a reduction of only one tariff may be welfare reducing.

2.6 Tariff reform without pollution reform

In this section, we analyse the optimal policy choice of a government which is constrained in setting the pollution tax. Being unable to alter environmental policy, trade policy is the only instrument the government can use in order to influence both the environmental outcome and the terms of trade. With two targets and one instrument, the outcome is necessarily a second-best.

If the pollution tax cannot be changed, Equation 2.18 reduces to

$$\begin{aligned} E_u du = &-[\delta_z G_{sq} - t'H_{qq}]\Lambda^{-1}H^*_{pp}dt \\ &- M'\Lambda^{-1}(H_{qq} + E_{qz}G_{sq})dt \end{aligned}$$

The second best tariff satisfies $E_u du/dt = 0$ or

$$-[\delta_z G_{sq} - t'H_{qq}]\Lambda^{-1}H^*_{pp} - M'\Lambda^{-1}(H_{qq} + E_{qz}G_{sq}) = 0. \tag{2.19}$$

Assuming that H^*_{pp} is invertible and using the definition of Λ and δ_z, we can solve for the second-best tariff as

$$t' = M'\Lambda^{-1}(H_{qq}+E_{qz}G_{sq})H^{*-1}_{pp}\Lambda(H_{qq}+E_{qz}G_{sq})^{-1}+(E'_z-s')G_{sq}(H_{qq}+E_{qz}G_{sq})^{-1}.$$

This simplifies to

$$t' = M'(H^*_{pp})^{-1} + (E'_z - s')G_{sq}(H_{qq} + E_{qz}G_{sq})^{-1}. \tag{2.20}$$

The notation in Equation 2.20 can be simplified. Based on Equation 2.4 and the goods market equilibrium condition 2.6, domestic imports M equal foreign exports $X^* = G^*_p - E^*_p$. Since H^*_{pp} is defined as $G^*_{pp} - E^*_{pp}$, it is the derivative of foreign exports with respect to the price and can be written as X^*_p. The matrix G_{sq} captures the change in pollution in response to changes in the domestic price (based on Equation 2.5). In order to highlight this, we use the notation $G_{sq} = -\partial z/\partial q$. These changes in notation yield the second-best tariff t^*

$$t^{*'} = X^{*'}(X^*_p)^{-1} - (E'_z - s')\frac{\partial z}{\partial q}(H_{qq} - E_{qz}\frac{\partial z}{\partial q})^{-1} \tag{2.21}$$

The second-best tariff t^* is the welfare maximizing tariff if the government is constrained in the way it sets its pollution policy.

The two terms on the right hand side of Equation 2.21 reflect the regulator's two targets. The first term represents the terms of trade motive. It equals the optimal tariff for a large country shown in Equation 2.11. The second term captures the environmental motive to manipulate the tariff. The next few sections of this chapter investigate this environmental motive in more detail.

2.7 A simple formula for the second-best tariff

2.7.1 Definition of pollution intensity and damage intensity

The interpretation of the second best tariff is facilitated if we make use of Copeland (1994)'s definition of pollution intensity. Copeland (1994) defines industry i as *pollution intensive in pollutant k* if an increase in the price of good i raises the emissions of pollutant k, i.e. if $dz_k/dq_i > 0$. An increase in the price of good i leads to an expansion of industry i, drawing resources from other industries. If the expanding industry emits more of pollutant k at the margin, than the contracting part of the economy, industry i is pollution intensive with respect to pollutant k.

We can define a good i as *damage intensive*[9] if $\sum_k (E_{z_k} - s_k)\frac{\partial z_k}{\partial q_i} =$

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[9] Note that the definition of damage intensity used here differs from the one used by

$-\sum_k (E_{z_k} - s_k)\frac{\partial G_{s_k}}{\partial q_i} > 0$. Damage intensity takes the weighted average of all pollutants into account. The weights are defined by the difference between marginal damage and the pollution tax. A pollutant for which the pollution tax is much lower than marginal damage receives a larger weight than a pollutant for which the pollution tax is close to marginal damage.

2.7.2 Assumptions

In order to obtain tractable comparative static results which can guide an empirical analysis, we impose slightly more structure on the economy.

Assumption 1. *Compensated demand for good i, E_{q_i}, is independent of emissions of pollutant k, i.e.* $\frac{\partial E_{q_i}}{\partial z_k} = 0$.

This assumption implies that any disutility which is generated due to pollution is compensated through additional consumption of the numeraire.

Given Assumption 1, the matrix E_{qz} is a matrix of zeros and the second best tariff simplifies to

$$t^{*'} = X^{*'}(X^*_p)^{-1} - (E'_z - s')\frac{\partial z}{\partial q}H^{-1}_{qq}. \tag{2.22}$$

Note that we have implicitly assumed that the matrix H_{qq} is invertible. Invertibility of H_{qq} implies that H_{qq} is a positive definite matrix rather than a positive semidefinite matrix and that the determinant of H_{qq} is positive.

Assumption 2. *Cross-price elasticities are zero, i.e.* $H_{q_i q_j} = 0 \; \forall \; i \neq j$

This assumption simplifies the explanation of the second best tariff considerably and allows us to convey a good intuition for the environmental motive to manipulate the import tariff. However, the main comparative static results also hold in an environment in which cross-price elasticities are positive but considerably smaller, in absolute terms, than own-price elasticities. This is shown in Appendix 1.

Note that even in the absence of cross-price elasticities, general equilibrium effects still play a role in this model through the reallocation of resources. A tariff reduction reduces the domestic price and leads to the contraction of an industry. As a result, pollution declines. The resources that are set free are used in other sectors and generate pollution in other sectors. The definition of the pollution intensities captures this effect.

Copeland (1994). Copeland (1994) defines a good as damage intensive if $\sum_k (E_{z_k} - t' E_{qz_k} - s_k)\frac{\partial z_k}{\partial q_i} > 0$.

With the cross-price elasticities equal to zero, invertibility of H_{qq} implies that $H_{q_i q_i} > 0 \, \forall \, i \neq j$. $H_{q_i q_i} = -\frac{\partial M_{q_i}}{\partial q_i}$ is the slope to the domestic import demand curve for good i. Hence, invertibility of H_{qq} and Assumption 2 ensure that the domestic import demand falls in the response to an increase in the price of good i and that $-\frac{\partial M_{q_i}}{\partial q_i} > 0$. Since the own-price elasticity of import demand is non-positive in the context of our model, the invertibility of H_{qq} only rules out the case in which import demand does not respond to the domestic price at all.

2.7.3 The simplified second-best tariff

Using Assumptions 1 and 2 as well as Equation 2.21, the second-best tariff for good i can be written as

$$t_i^* = \frac{X_i^*}{\frac{\partial X_i^*}{\partial p_i}} + \frac{1}{\frac{\partial M_{q_i}}{\partial q_i}} \left(\sum_k (E_{z_k} - s_k) \frac{\partial z_k}{\partial q_i} \right) \tag{2.23}$$

The first term on the right hand side captures the terms of trade motive to manipulate the tariff. The terms of trade motive is given by the inverse of the foreign elasticity of export supply. The lower the elasticity of foreign export supply, the higher the tariff. If foreign supply is relatively unresponsive to changes in the world market price, then it is optimal to set a high tariff. If the home economy is a small economy, then the foreign elasticity of export supply is infinite and the terms of trade motive is zero.

The second term on the right-hand side determines the environmental motive to manipulate the tariff.

The two motives are additive[10] and the terms of trade motive to introduce and export tax is not a function of the pollution intensity or the gap between marginal damage and the pollution tax. Moreover, the environmental motive to introduce export taxes is independent of the terms of trade motive.

2.7.4 Comparative statics

Result 1. The second-best tariff for good i declines in the damage intensity of good i.

The partial derivative of the second best tariff in Equation 2.23 with respect to the damage intensity is given by

$$\frac{\partial t_i^*}{\partial \left(\sum_k (E_{z_k} - s_k) \frac{\partial z_k}{\partial q_i} \right)} = \frac{1}{\frac{\partial M_{q_i}}{\partial q_i}}. \tag{2.24}$$

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[10] Note that this hold even without the simplifying Assumptions 1 and 2.

Since the term $\frac{\partial M_{q_i}}{\partial q_i}$ is negative, the tariff is lower for goods with a higher damage intensity $\sum_k (E_{z_k} - s_k)\frac{\partial z_k}{\partial q_i}$, ceteris paribus. If the good is sufficiently polluting, the second-best trade policy might be an import subsidy even though the terms of trade motive requires a positive import tariff. The following example illustrates the point. If a country is a large importer of paper products on the world market, there is an incentive to levy a tariff on paper imports in order to reduce the world market price for these products. This is the terms of trade motive. The tariff would lead to the expansion of the paper industry in China. However, if paper production is very damage intensive, the government might actually choose to subsidize imports of paper products in order to relocate the polluting production abroad and reduce domestic pollution.

Result 2. The second-best tariff for good i declines in the pollution intensity of good i with respect to pollutant k, if the pollution tax for pollutant k is lower than marginal damage.

The partial derivative of the second-best tariff in Equation 2.23 with respect to the pollution intensity is

$$\frac{\partial t_i^*}{\partial \frac{\partial z_k}{\partial q_i}} = \frac{E_{z_k} - s_k}{\frac{\partial M_{q_i}}{\partial q_i}}. \tag{2.25}$$

The sign of the partial derivative in Equation 2.25 depends on the difference between marginal damage and the pollution tax. If the pollution tax for pollutant k is lower than marginal damage, i.e. environmental regulation is too lenient, the second-best tariff declines in a product's pollution intensity with respect to pollutant k, since the term $\frac{\partial M_{q_i}}{\partial q_i}$ is negative. The intuition for this result is straightforward. With lenient environmental regulation, pollution is above the optimum. Lower tariffs can mitigate this outcome. As a result of lower tariffs, imports increase and some of the pollution intensive production takes place abroad rather than in the domestic economy.

If production of good i is not pollution intensive with respect to pollutant k, the tariff can be higher than the first best tariff. The second-best tariff protects clean industries. If more resources are allocated to those industries, overall pollution declines.

Equation 2.25 also shows that the tariff is independent of the pollution intensity if the government sets the first best pollution tax, which is equal to marginal damage.

Result 3. The second-best tariff for good i declines in the gap between marginal damage and the pollution tax for every pollutant which good i

generates intensively.

Holding everything else constant, the tariff for a pollution intensive good is lower if environmental regulation is very lenient for the pollutants which are generated intensively during the production of the product. This is obvious from the partial derivative below, where the term $\frac{\partial M_{q_i}}{\partial q_i}$ is negative:

$$\frac{\partial t_i^*}{\partial E_{z_k} - s_k} = \frac{1}{\frac{\partial M_{q_i}}{\partial q_i}} \frac{\partial z_k}{\partial q_i}. \tag{2.26}$$

The partial derivatives 2.24 and 2.25 show that an increase in the damage intensity and the pollution intensity has a larger impact on the second-best tariff if the import demand curve of the domestic economy is relatively steep ($\frac{\partial M_{q_i}}{\partial q_i}$ is relatively small in absolute terms). This is intuitive, since the increase in the tariff has to be higher to achieve the same change in the import demand if import demand is relatively unresponsive to price changes.

2.8 Application of the model to export taxes

The previous sections of this chapter focused on import tariffs. However, the model can also be used to describe second-best export taxes. This case is of particular interest for the empirical analysis in Chapter 2 of this thesis.

Export taxes drive a wedge between a product's domestic price and the world market price in a similar way as import tariffs. With an export tax vector x, the domestic price q relates to the world market price p in the following way: $q + x = p$. Rewriting this equation in the form $q = p - x$ shows that an export tax is like a negative import tariff in the context of our model. Multiplying Equation 2.23 by -1 gives us the second-best export tax vector, x^*, as

$$x^{*'} = -M^{*'}(M_p^*)^{-1} + (E_z' - s')\frac{\partial z}{\partial q}\left(X_q + E_{qz}G_{sq}\right)^{-1} \tag{2.27}$$

where $M^{*'} = G_p^* - E_p^*$ are foreign imports, M_p^* is the change in foreign imports in response to changes in the world market price and X_q represents the change in domestic exports in response to a change in the domestic price.

With assumptions 1 and 2, this formula gives us the export tax for product

i, x_i^*, as

$$x_i^* = -\frac{M_i^*}{\frac{\partial M_i^*}{\partial p_i}} + \frac{1}{\frac{\partial X_{q_i}}{\partial q_i}} \left(\sum_k (E_{z_k} - s_k) \frac{\partial z_k}{\partial q_i} \right). \tag{2.28}$$

The first term on the right hand side captures the terms of trade motive to manipulate the export tax. The export tax depends on the inverse of the foreign elasticity of import demand. If foreign preferences are well-behaved and the matrix M_p^* is invertible, then $\frac{\partial M_i^*}{\partial p_i} < 0$ and $-\frac{M_i^*}{\frac{\partial M_i^*}{\partial p_i}} > 0$. Hence, the higher the foreign elasticity of import demand, the lower the export tax. If the home economy is a small economy, then the foreign elasticity of import demand is infinite and the terms of trade motive to manipulate the export tax disappears.

The second term on the right-hand side determines the environmental motive to manipulate the export tax. The interpretation is parallel to the interpretation of the environmental motive for the import tariff. Since we assumed that export supply increases in the domestic price, the term $\frac{\partial X_{q_i}}{\partial q_i}$ is positive. Hence, the export tax is higher for goods with a higher damage intensity $\sum_k (E_{z_k} - s_k) \frac{\partial z_k}{\partial q_i}$, ceteris paribus. Moreover, the second-best export tax increases in the pollution intensity $\frac{\partial z_k}{\partial q_i}$ of good i with respect to pollutant k, given that the gap between marginal damage and the pollution tax is positive. A larger gap between marginal damage and the pollution tax raises the effect of the pollution intensity on the second-best export tax.

In addition, an increase in the damage intensity or the pollution intensity has a higher impact on the second-best tariff if the export supply curve of the domestic economy is relatively steep ($\frac{\partial X_{q_i}}{\partial q_i}$ is relatively low). With a steep export supply curve, the price needs to drop more in order to reduce output to the same extent as with a flat export supply curve.

2.9 Policy implications

The theoretical model presented above demonstrates that import tariffs and export taxes can be used as second-best policy instruments if the regulator cannot implement the first best pollution tax. This scenario is particularly relevant for countries which struggle to implement and enforce domestic environmental regulation due to corruption.

The model yields practical implications for the implementation of second-best export taxes. Firstly, there should be a positive correlation between the export tax and the product's damage intensity. In other words, the government should implement the highest export tax for the most polluting goods. If the export tax is highest for goods with an intermediate or low damage intensity, the policy might lead to a reallocation of resources into more damaging activities and might thus be harmful in environmental terms.

The damage intensity is defined as the weighted average of all pollution intensities. This implies that the export tax needs to target a weighted average of all pollutants. If the government implements high export taxes for goods which are pollution intensive in one particular pollutant (e.g. SO_2) and ignores all other pollutants, resources are reallocated into the production of goods which might be pollution intensive with respect to another pollutant. This other pollutant could be even more harmful or reduce welfare even more than SO_2.

Each pollutant's weight is defined by the gap between marginal damage and the pollution tax. If marginal damage is high and the pollution tax is low, the pollutant will receive a high weight. Marginal damage captures the consumer's willingness to pay for a one unit reduction in pollution. It also reflects factors like the impacts of additional pollution on the consumer's health. Marginal damage is difficult to measure and the policy maker is unlikely to have precise information on marginal damage. However, the consumer's willingness to pay for a reduction in pollution is likely to be higher for pollutants with severe negative health impacts, for example. Studies on the cost of pollution for human health could be a first guideline for policymakers who implement a second-best export tax.[11]

For a large country, export taxes can also be motivated by an attempt to manipulate the terms of trade in a country's favour. The analysis has shown that the terms of trade motive and the environmental motive to set export taxes are additive. A country which levies an export tax for a particular product i in order to achieve a better price for its exports, would raise the export tax for product i over and above the first best export tax when it introduces an environmentally motivated second-best export tax if product i is damage intensive.

2.10 Conclusion

Our theoretical analysis shows that both import tariffs and export taxes can be used as a second-best policy instrument if the regulator cannot set

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[11] World Bank (2007), for example, estimates the cost of water and air pollution in China including the cost of pollution on health.

welfare-maximizing pollution taxes.

In a general equilibrium model for a large country which produces many goods and generates many local pollutants during the production process, we show that the first best policy requires the use of domestic pollution taxes in order to internalize the environmental distortion. The first best tariff or export tax is used to achieve the optimal terms of trade. This is in line with finding in the previous literature (e.g. Markusen, 1975; Copeland, 2011).

The use of import tariffs and export taxes which reflect environmental concerns is welfare maximizing in a situation in which the domestic regulator cannot implement the first best pollution tax. The second-best import tariff or export tax are functions of the pollution intensities in production and the gap between marginal damage caused by a pollutant and the pollution tax. The model shows that the second-best import tariff declines in a product's pollution intensity. With low tariffs, imports work as a substitute for domestic production. Hence, pollution in the domestic economy declines.

In a similar vein, the model reveals that second-best export taxes increase in a products pollution intensity. An export tax discourages the production of polluting products for export markets and hence reduce domestic pollution. These results guide our empirical analysis in the next chapter.

Appendix

The simplified formula for the second-best tariff assumes that all the cross-price elasticities are equal to zero. However, Assumption 3 is not necessary in order to get the comparative static results 2.24 and 2.25 that the second-best tariff for good i declines in the damage intensity and the pollution intensity of good i. If we do not assume that the cross-price elasticities are zero, the partial derivative of the tariff of good i with respect to the damage intensity of good i is characterised by the following Equation:

$$\frac{\partial t_i}{\partial\left(\sum_k (E_{z_k} - s_k)\frac{\partial z_k}{\partial q_i}\right)} = -\frac{1}{|H_{qq}|} adj(H_{qq})_{ii} \tag{2.29}$$

where $adj(H_{qq})_{ii}$ is the element in row i and column i of adjugate matrix of H_{qq}, $\mathrm{adj}(H_{qq})$, and $|H_{qq}|$ is the determinant of H_{qq}. The latter is positive if H_{qq} is invertible. Hence, the tariff declines in the damage intensity as long as the diagonal elements of the adjugate matrix, $adj(H_{qq})$, are positive. This is the case if the own-price elasticities are sufficiently large, in absolute terms, compared to the cross-price elasticities.

Similarly, the partial derivative of the second-best tariff for good i with respect to the pollution intensity of good i in pollutant k is given by

$$\frac{\partial t_i}{\partial \frac{\partial z_k}{\partial q_i}} = -\frac{E_{z_k} - s_k}{|H_{qq}|} adj(H_{qq})_{ii}. \tag{2.30}$$

This partial derivative is negative as long as $adj(H_{qq})_{ii} > 0$.

3 Is Chinese trade policy motivated by environmental concerns?

Abstract

This chapter analyses whether China's export VAT rebates and export taxes are driven by environmental concerns. Since China struggles to enforce environmental regulation, trade policy can be used as a second best environmental policy. In a general equilibrium model it is possible to show that the second-best export tax increases in a product's pollution intensity. The empirical analysis investigates whether the overall export tax is higher for products which are more pollution intensive along several dimensions. The results indicate that the overall export tax is set in a way that discourages exports of water pollution intensive and energy intensive products as well as natural resources from 2007 on.

3.1 Introduction

Since 2007, China has introduced export taxes and reduced export value-added tax (VAT) rebates for a range of products. According to China's National Development and Reform Commission, the VAT rebate adjustments aim at controlling "exports of energy-intensive, pollution-intensive and resource-intensive products, so as to formulate an import and export structure favorable to promote a cleaner and optimal energy mix" (NDRC, 2007, p. 31). Statements which link VAT rebates and export taxes to environmental concerns appeared repeatedly in consecutive years (Wang et al., 2010; WTO, 2008).

This chapter investigates whether, in practice, Chinese trade policy reflects environmental motives. We study the Chinese government's decision to choose a particular export tax rate or VAT rebate rate and analyse whether the choice of export taxes and VAT rebate actually reflects an attempt to reduce pollution and conserve resources.[1]

It is not obvious that the VAT rebate and export tax adjustments are driven by environmental concerns. Other potential motives include an attempt to manipulate the terms of trade in China's favour, a desire to attract downstream producers to China or lobbying pressure by different industries.

The policy relevance of the motivation behind Chinese export restrictions manifests itself in two WTO dispute settlement cases. The first case concerns Chinese export restrictions on raw materials and was filed in 2009 (WTO, 2013a). The second case was filed in March 2012 and deals with export restrictions on rare earths (WTO, 2014). In both cases China is a leading producer of the goods in question which are used as intermediate inputs into high-tech products. The complainants hold that China uses export restrictions to manipulate the world market price and to force intermediate producers to move to China where supply of these crucial inputs is stable. China, however, argues that the export restrictions are necessary to protect China's natural resources and the health of its citizens since the production is highly polluting. Even though China committed to cancelling its export taxes on most products in its Accession Protocol to the WTO, it argues that the export restrictions are justified under Article XX of the GATT. Article XX of the GATT allows an exemption from GATT rules for environmental

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[1] This thesis does not study the effect of export taxes or partial VAT rebates on curbing exports or reducing pollution. We study the factors which motivate the Chinese government to choose a particular tax rate.

objectives such as the protection of exhaustible natural resources and health considerations (WTO, 2013b).

The export VAT rebate and export tax reforms have to be assessed against the background of China's environmental agenda. In the last decade, the Chinese government has launched an ambitious attempt to tackle the country's environmental problems. There are several reasons for this increasing focus on environmental policy. Firstly, the Chinese leadership realized that environmental problems might hamper China's growth in the long run. Secondly, public discontent concerning pollution has been growing (Gang, 2009, p. 119). This has become obvious in mass protests in response to environmental degradation and in increasing participation in environmental NGOs. Gang (2009) argues that addressing environmental issues might be crucial for the government to consolidate its rule. Finally, international pressure on China to adopt stricter environmental policies is increasing.

It is well-known that local environmental distortions are best internalized through the use of domestic policy instruments such as pollution taxes (see e.g. Copeland, 2011). Copeland (1994), however, shows that a country which fails to implement optimal pollution regulation can use trade policy as a second-best instrument to reduce pollution. Arguably, the second-best scenario applies to China. The Chinese government attempts to reduce pollution. This is reflected in ambitious targets for environmental protection in recent Chinese Five Year Plans. However, the design of the Chinese pollution levy system and difficulties with the enforcement of environmental regulation limit the Chinese government's ability to use pollution levies in order to reduce domestic pollution. Trade policy instruments like export taxes and partial export VAT rebates can, thus, be used as second-best environmental policy instruments.

The theoretical foundation for our analysis is an extension of Copeland (1994)'s model to a large country which sets trade and environmental policy unilaterally. The first chapter of this thesis solves the model for the second-best export tax and shows that the latter increases in a product's pollution intensity. The intuition behind this result is simple: The export tax reduces production and exports of a particular good. As a result, resources are reallocated to sectors which are subject to a lower export tax. If the export tax is largest for the most pollution intensive goods, more resources are allocated to the production of relatively clean goods and the pollution intensity of production declines.

The prediction that the second-best export tax is positively correlated with a product's pollution intensity guides our empirical analysis. We investigate whether the overall export tax is higher for products which are more pollution intensive along several dimensions. The analysis considers pollutants for which the Chinese government has specified emission reduction targets in its Five Year Plans. These include waste water, chemical oxygen demand (COD), ammonium nitrogen, soot, SO_2, solid waste and energy use.

The dataset used for this analysis covers the years 2005 to 2009. Since Chinese officials repeatedly linked trade policy to environmental concerns from 2007 on, we are particularly interested in the relationship between trade policy variables and pollution intensities for the years 2007 to 2009. The data for the years 2005 and 2006 allow us to test whether there is a stronger link between trade policy variables and pollution intensities as a consequence of the VAT rebate and export tax reforms from 2007 on compared to the situation prior to 2007.

The results indicate that Chinese trade policy reflects environmental concerns. The overall export tax is larger for industries with a higher water pollution intensity and energy intensity from 2007 on but not prior to 2007. This pattern is in line with the actions of a regulator who adjusts the overall export taxes to reduce exports of water-pollution intensive and energy intensive products and confirms the Chinese government's claim that trade policy adjustments aim at reducing pollution and energy use.

However, the overall export tax does not seem to be used as a second-best instrument to reduce air pollution and solid waste or to increase recycling. Since China overachieved it Five-Year-Plan targets to reduce solid waste and increase recycling, domestic measures may suffice to reduce pollution along those dimensions.

Our analysis also confirms that Chinese trade policy is used to conserve natural resources. The overall export tax is significantly higher for wood, mineral and metal products as well as precious stones, indicating that the overall export tax is used to curb exports of those resources. This is particularly evident for the period from 2007 to 2009.

Moreover, the overall export tax is significantly higher for primary products throughout the sample period. This could create an incentive for downstream producers to relocate to China in order to get access to raw materials at a lower price.

The regression results show that the determinants of the export tax differ considerably from the determinants of the VAT rebates. From 2007 on, the difference between the VAT and the VAT rebate is higher for water pollution and energy intensive products as well as natural resources. The export tax increases in a product's solid waste intensity. Moreover, primary products are subject to higher export taxes.

This chapter is structured as follows. Section 3.2 reviews the relevant literature, followed by information on the policy background for our study in Section 3.3. In Section 3.3.1 we argue that environmental problems play a prominent role on the Chinese policy agenda, but that the government struggles to implement and enforce effective domestic pollution taxes. Section 3.3.2 explains why partial export VAT rebates are similar to export taxes. Section 3.3.3 provides background information on Chinese export taxes.

This chapter analyses whether reforms of export taxes and export VAT rebates are driven by an attempt to reduce pollution and energy use. In Section 3.4 summarizes the theoretical background for our analysis. It repeats the formula for the second-best export tax which was derived in Chapter 1 and highlights that the second-best export tax increases in a product's pollution intensity. This prediction is the foundation for our empirical analysis. We investigate whether the export tax and the VAT tax are higher for more polluting products. The precise empirical strategy is explained in Section 3.5. This chapter looks at the determinants of the export tax, the VAT tax (defined as VAT-export VAT rebate) as well as the overall export tax, which is the sum of the export tax and the VAT tax. Each of these variables is analysed as a function of the pollution intensities and a set of control variables. The choice of control variables is explained in Section 3.5.2.

Section 3.6 describes the dataset followed by summary statistics in Section 3.7. The regression results are presented in Section 3.8 followed by a sensitivity analysis in Section 3.9. Section 3.10 concludes.

3.2 Related literature

To the best of our knowledge, Wang et al. (2010) provide the only analysis of the environmental aspects behind China's trade policy. Wang et al. (2010) calculate the implicit export carbon tax behind China's export taxes and export VAT rebates for 8 energy-intensive sectors and find that the implicit export carbon tax differs considerably across sectors. The implicit export carbon tax ranges from 18 US$ per ton of CO_2 emissions for basic chemicals to 764 US$ for chemical fibre.

Yet, this finding does not imply that the VAT rebate and the export tax reforms are not based on environmental concerns. CO_2 emissions may not have been the Chinese government's only concern when it designed the policy. We control for political economy motives and study the relationship between trade policy instruments and a range of pollutants as well as energy use. This reveals whether Chinese trade policy reflects concerns about air, water or solid waste pollution and will indicate which pollutant has the largest impact on the respective trade policy instruments. As opposed to Wang et al. (2010) we consider the overall pollution generated in all stages of the production process and not only a sector's direct pollution emissions.

Empirical work which explicitly takes the relationship between tariffs and pollution regulation or pollution intensity into consideration, is very sparse. One exception is the paper by Ederington and Minier (2003), which looks at pollution policy as a second-best trade barrier. If the regulator regulator is constrained in setting import tariffs due to WTO membership, lenient environmental policy reduces production cost and can thus be used as a secondary means to protect the domestic industry. This would suggest that environmental policy is more lenient in industries in which tariffs are lower. However, the empirical results show the opposite. Tariffs are negatively correlated with environmental regulation.

This chapter analyses the determinants of trade policy instruments. The choice of our control variables is guided by the literature on the political economy of protection. Baldwin (1989); Gawande and Krishna (2003); Ethier (2011) provide excellent surveys of that literature. We will refer to the relevant papers for our work in the section that explains the choice of the control variables. Three papers, which analyse Chinese trade policy, however, are worth describing in detail.

Wang and Xie (2010) study the industry characteristics which determine the structure of Chinese VAT rebates in 2008. Wang and Xie (2010) find that industries with a higher export share have a higher rebate rate, since China supports an export-oriented strategy. The VAT rebate rate is also positively related to the share of national capital. This is interpreted as a sign that state-owned enterprises (SOEs) receive a favourable treatment. Moreover, Wang and Xie (2010) argue that the VAT rebate rates reflect an attempt to reduce adjustment cost and achieve social stability, as reflected by the fact that the rebate rate is higher for less profitable industries, industries with a lower labour productivity and industries with a lower ratio of value added. The results also show that industries with more assets, a large number of firms and a large presence of foreign capital receive higher VAT rebates. Just as in our study, they find that export VAT rebates, export taxes and tariffs are complementary. Industries which receive higher VAT rebates also face lower export taxes and higher protection on the import side. Chen and Feng (2000) analyse the determinants of Chinese tariffs and find that most of the variation in tariffs can be explained by information on industry size.

The complainants in the WTO dispute settlement cases against China hold that China introduced export taxes on primary products in order to induce downstream producers to relocate to China. Garred (2014)'s findings support this hypothesis in showing that the joint export tax equivalent of Chinese export taxes and VAT rebates increased faster for raw materials than for other products over a sample period from 2002 to 2012. Even though we focus on cross-sectional variation rather than variation over time, we also come to the conclusion that the export tax and the VAT rebate jointly discourage exports of primary products.[2]

The papers by Wang and Xie (2010), Garred (2014) and Chen and Feng (2000) highlight important determinants of Chinese trade policy. Their findings guide the choice of our control variables. However, our study differs considerably from Wang and Xie (2010), Garred (2014) and Chen and Feng (2000). While we are mostly interested in the relationship between VAT rebates or export taxes and pollution intensities, this aspect is completely neglected in Wang and Xie (2010), Garred (2014) and Chen and Feng (2000).

3.3 Policy background

3.3.1 Environmental policy in China

In recent years, the Chinese government has launched an ambitious agenda to tackle the country's environmental problems. Firstly, it adopted ambitious targets to reduce pollution and energy consumption in recent Five Year Plans (FYPs). During the sample period of our study, the Chinese government aimed at reducing air pollution, water pollution as well as the generation of solid waste. Moreover, China planned to considerably reduce energy

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[2] Evenett et al. (2012) also describe Chinese VAT rebate reforms and highlight that there is significant variation in VAT rebate rates across time and products. However, they do not analyse the motives behind these adjustment in detail.

consumption per unit of GDP.[3]

In addition to ambitious environmental targets, the Chinese government undertook substantial reforms of its administrative structure to give environmental protection a more prominent role in its political hierarchy (Gang, 2009). The State Environmental Protection Agency was elevated to the rank of a Ministry in 2008 and received a larger budget and more staff. Moreover, China set up a National Leading Group to Address Energy Saving, Emission Cutting and Climate Change. It is headed by the Premier and has thus got a high rank in the political hierarchy. I addition to that, the government started to incentivize local leaders to protect the environment by linking the measure for local officials' performance not only to economic growth but also to environmental achievements.

Even though China embraced ambitious attempts to protect the environment, the lack of enforcement is "the single biggest weakness in China[']s environmental law" (Stalley, 2010, p. 33). The implementation and enforcement of environmental regulation is decentralized to a large extent (Ren and Shou, 2013; Stalley, 2010). The national authority (the State Environmental Protection Agency, SEPA) specifies emission standards for most pollutants.[4] The implementation of environmental regulation and the collection of levies is in the hands of provincial and municipal local environmental protection bureaus (EPBs).[5]

Local EPBs often lack the power to implement the regulations for several reasons. Firstly, even though their personnel has grown, EPBs are still short of staff to guarantee satisfactory implementation (Ren and Shou, 2013; Stalley, 2010; Brettell, 2013). Secondly, local environmental agencies lack the skills and the technology to detect infringements of pollution standards (Ren and Shou, 2013). Thirdly, local firms are an important source of government revenue and are thus promoted by local authorities. Pollution emissions from these firms are often ignored or permitted. If local leaders consider a certain company important for the local economy, Environmental Protection Bureaus are often impeded from collecting levies (Dean et al., 2009; OECD, 2005).

Endemic corruption exacerbates the weak enforcement power of local

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[3] Table 3.15 in the Appendix lists the relevant emission reduction targets for the years 2001 to 2010.

[4] See Article 10 of the Environmental Protection Law of the People's Republic of China (NPC, 1989).

[5] According to Article 16 of China's National Environmental Protection Law "the local people's governments at various levels shall be responsible for the environment [sic] quality of areas under their jurisdiction and take measures to improve the environment quality" (NPC, 1989)

environmental agencies (Stalley, 2010). There is ample anecdotal evidence that local authorities negotiate levy payments with firms (Dean et al., 2009; OECD, 2005; Wang et al., 2003). The precise environmental cost of corruption is difficult to estimate, but it is likely to be significant. According to a statement by Zhou Shengxian, the director of the State Environmental Protection Agency, in 2006, the government investigated pollution control approvals for construction projects and discovered violations in about 40 percent of the cases (Stalley, 2010, p. 35).

Enforcement is further impeded due to the weakness of China's courts, which hampers environmental litigation and by the marginal influence of stakeholders and environmental NGOs (Stalley, 2010).

Even if pollution regulation is enforced and levies are collected, environmental policy can only be effective if it induces producers to reduce pollution. However, empirical evidence on the deterrent effect of pollution regulation is mixed. Wang et al. (2003) use Chinese province level data on water pollution and come to the conclusion that a higher effective pollution levy significantly reduces pollution intensities. Wang and Wheeler (2005) corroborate the finding of a significant deterrent effect of effective pollution levies on SO_2 and COD. Dust emissions, however, are not significantly affected by the pollution levy. Note, however, that the latter two studies are based on effective pollution levies. Effective pollution levies are the levies which are actually collected by the local authorities and not the levies which should be collected based on official pollution regulation. Since the local authorities have a considerable amount of leeway when it comes to the collection of pollution levies, the effective levy also incorporates an element of enforcement. The importance of enforcement is also highlighted in Dasgupta et al. (2001), who find that inspections by the Environmental Protection Bureau significantly reduce pollution. In a model which controls for inspections, effective pollution levies do not deter emissions. Moreover, Cole et al. (2008) find that neither formal nor informal regulation have a deterrent effect on industry level emissions.

The substantial leeway that local governments have in implementing and enforcing environmental regulation as well as a questionable deterrent effect of pollution levies make it difficult for the central government to tighten environmental policy in China. Hence, trade policy might be a second-best option to reduce domestic pollution in China.

3.3.2 Policy background: Export value-added tax rebates

Since the mid 2000s, the Chinese government has adjusted VAT rebate rates on a frequent basis. The Chinese government quotes environmental protection as a main motivation for these adjustments. According to the Communication on China's Policies and Action for Addressing Climate Change[6] these VAT rebate adjustments are geared towards reducing energy intensive and polluting exports and can be considered part of China's climate policy. However, environmental concerns were not the only motive for the VAT rebate rate adjustment. The reforms were also meant to serve China's development strategy and foster the production of high-tech and high-value added exports (Wang et al., 2010).

Most countries levy value added taxes. It is common practice to exempt exporters from VAT payments or refund the VAT that exporters paid for their intermediate inputs. In China, exporters only get partial VAT rebates. Partial export VAT rebates have similar effects as export taxes if the export destination levies VATs on its imports (Feldstein and Krugman, 1990). In the absence of (full) VAT rebates, producers face double taxation since they are taxed both in the country of origin and in the export destination. The partial refund is a comparative disadvantage for Chinese producers compared to producers from countries with full export VAT rebates. The lower the rebate rate, the higher the double taxation of exporters. Hence, a reduction in the VAT rebate rate has a similar effect as an increase in the export tax.

This theoretical prediction is supported by empirical evidence, which shows that partial export VAT rebates curb exports. Several studies have analysed the effect of Chinese export tax rebates and export VAT rebates on export performance at a fairly aggregate level (Chao et al., 2001; Chen et al., 2006; Chao et al., 2006). All of these studies find that higher export VAT rebates increase exports. Moreover, Chandra and Long (2013) estimate the effect of a reduction in VAT rebates on exports using firm level data for the years 2000 to 2006. Their findings suggest that an increase in the actual VAT rebate rate by one percentage point raises exports by 13% This estimate is surprisingly large and may be explained by the fact that Chandra and Long (2013) calculate VAT rebate rates using firm level data instead of using product level VAT rebate rate data. Gourdon et al. (2014) use data on VAT rebate rates at the HS6 digit product level and find that an increase in the VAT rebate rate by one percentage point leads to an

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[6] Information Office of the State Council of the People's Republic of China (2008)

increase in exports quantities by 6.5% for products which are eligible to VAT rebates.

Since there is ample theoretical and empirical evidence that partial VAT rebates have similar effects as export taxes, this chapter treats the difference between the VAT and the VAT rebate rate as an export tax.

3.3.3 Policy background: Export taxes

In its Accession Protocol to the WTO, China agreed to levy export taxes on no more than 84 product lines and the export taxes were not allowed to exceed a certain threshold. This threshold ranges between 20% and 40%, depending on the product.

In practice, China introduced export taxes on far more products since 2007. The first row in Table 3.1 shows that only 29 products at the HS8 digit level in our sample were subject to an export tax in 2006. In 2009, the government levied export taxes on 235 products in our sample.

Table 3.1: Products with export taxes

	(1) 2005	(2) 2006	(3) 2007	(4) 2008	(5) 2009
# of products with export tax > 0	29	39	129	255	235
Average export tax	0.093	0.128	0.294	0.629	0.651
Average export tax $\mid$ export tax > 0	18.517	18.929	13.252	14.370	16.034

3.4 Second-best export taxes as environmental policy

China seems determined to reduce its emissions but struggles to enforce pollution regulations to internalise the environmental distortion. Under these circumstances, an export tax can be used as a second-best environmental policy instrument.

The first chapter of this thesis derives a formula for the second-best export tax based on an extension of Copeland (1994)'s model to the large country case. In the model, a perfectly competitive large open economy produces or consumes $N_g + 1$ goods and the production process of all non-numeraire goods generates N_p different domestic pollutants which are captured in the pollution vector z. A benevolent regulator tries to achieve the welfare maximizing terms of trade and as well as the welfare maximizing pollution emissions. We focus on a situation in which the regulator cannot adjust environmental policy, but he unilaterally sets trade policy.[7] Under the assumption that compensated demand for good i is independent of pollution, we get the following formula for the second-best export tax:

$$x^{*'} = -\underbrace{M^{*'}(M_p^*)^{-1}}_{\text{Terms of trade}} + \underbrace{(E_z' - s')\frac{\partial z}{\partial q}(X_q)^{-1}}_{\text{Environmental motive}} \tag{3.1}$$

where x^* is the vector of second-best export taxes, M^* is the vector of foreign imports and M_p^* is the matrix of derivatives of foreign import demand with respect to the world market price p. E_z is vector of marginal damage for each pollutant k and s is a vector of pollution taxes. As long as $E_z > s$, the pollution tax is too lenient and does not internalize the environmental distortion. The matrix $\frac{\partial z}{\partial q}$ contains the pollution intensities. The concept of the pollution intensity is explained in more detail below. The matrix X_q captures the change in the domestic export supply of good i in response to changes in the domestic price of good j, q_j. We assume that the matrix X_q is invertible. This implies that the matrix X_q is positive definite.

The second-best export tax features a terms of trade motive and an environmental motive. The terms of trade motive captures the incentive to introduce an export tax in order to reduce the supply of the good on the world market. As long as the country is a large supplier on the world market, this drives up the world market price and allows the country to get a higher price for its exports. The terms of trade motive equals the inverse of the foreign elasticity of import demand.

The environmental motive reflects the attempt to reduce pollution through the use of export taxes. An export tax reduces production and hence reduces emissions which are generated during the production process. If the government increases the export tax for the most polluting product, the production of this pollution intensive product declines. The resources that are set free in the polluting sector are allocated to the production of cleaner goods. This way, the pollution intensity of production in the economy declines.

To be more precise about this concept, we follow Copeland (1994) and define good i as *pollution intensive in pollutant k* if an increase in the price of good i raises emissions of pollutant k, i.e. if $\partial z_k / \partial q_i > 0$. An increase in the price of good i leads to an expansion of industry i, drawing resources

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[7] A precise description of the model as well as the solution for second best export tax is available chapter 1.

from other industries. If the expanding industry emits more of pollutant k at the margin than the contracting part of the economy, industry i is pollution intensive with respect to pollutant k.

In order to show that the second-best export tax increases in a product's pollution intensity, we consider a world in which the cross-price elasticities of export supply are negligible. In other words, we look at a case in which all the off-diagonal elements of X_q are zero or considerably smaller, in absolute terms, than the own-price elasticities. In that case it is easy to see that the second-best export tax in Equation 3.1 increases in a product's pollution intensity as long as the domestic pollution tax does not internalise the environmental distortion ($E_z > s$).

3.5 Empirical strategy

3.5.1 Estimating equation

The Chinese government claims to use export taxes and VAT rebates to reduce "exports of energy-intensive, pollution-intensive and resource-intensive products" (NDRC, 2007, p. 31). Our empirical analysis tries to reveal whether, in practice, export taxes and export VAT rebates reflect an attempt to protect the environment. If the export taxes or equivalent policy instruments are motivated by environmental concerns, or in other words, if the export tax is a secondary pollution policy, then the export tax should be higher for more polluting products as long as environmental policy is too lenient. Hence, this chapter analyses the relationship between trade policy variables and pollution intensities.

Our estimating equation is motivated by Equation 3.1:

$$y_{it} = \alpha_0 + \sum_k \beta_k Reg\_gap_{itk} * pol\_int_{itk} + Controls_{it} + \delta_t + \varepsilon_{it} \qquad (3.2)$$

where the dependent variable y_{it} is the export tax for product i at time t or its equivalent. We look at three different dependent variables: the export tax, the VAT tax and the overall export tax. The latter two variables are defined below.

The variable Reg_gap_{itk} is the share of emissions not meeting discharge standards. This variable is a proxy for the difference between marginal damage and the pollution tax ($E_z - s$) for pollutant k at time t. pol_int_{itk} represents the overall pollution intensity of exports with respect to pollutant

k. The interaction term $Reg\_gap_{itk} * pol\_int_{itk}$ follows Equation 2.28 and reflects the fact that the relationship between the pollution intensity and the export tax or its equivalent should be stronger, the larger the gap between marginal damage and the pollution tax. Time fixed effects are represented by δ_t and ε_{it} is the idiosyncratic error term.

The VAT tax is defined as

$$VATtax_i = VAT\ rate_i - export\ VAT\ rebate\ rate_i. \tag{3.3}$$

The VAT tax captures the export tax equivalent of partial VAT rebates. Due to the double taxation of exports, a lower VAT rebate rate or a higher VAT tax hamper exports. The chapter analyses the determinants of the VAT tax rather than the VAT rebate rate. An analysis of the VAT rebate rate itself is not informative due to differences in the value-added tax across products. The VAT amounts to 17% for most goods and 13% for some agricultural products. A small range of products is not subject to a VAT. A VAT rebate of 5% generates a lower burden for an exporter whose final product is subject to a VAT of 13% rather than 17%. In order to asses the burden of the partial VAT rebate policy on producers, it is necessary to use information on VATs.[8]

In addition to the export tax and the VAT tax, we look at the overall export tax that is levied on exports of a particular product. We add up the export tax and the VAT tax to generate a variable called *Overall export tax* which is defined as

$$Overall\ export\ tax_i = VAT\ tax_i + export\ tax_i. \tag{3.4}$$

Looking at the overall export tax brings us closest to the predictions of the theoretical model. The theoretical model does not distinguish between the actual export tax and the partial VAT rebate. It highlights that the overall export tax should be largest for industries which are most pollution intensive in a particular pollutant if the regulator uses trade policy as a second-best pollution policy. This relationship holds as long as the gap between marginal damage and the pollution tax is positive for the respective pollutant.

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[8] The VAT rebate rule which applies to most products can be summarised by the following formula (Chan, 2008): *VAT rebate= input VAT - (value of export sale - value of bonded materials)*(VAT rate - rebate rate).* This implies that it is appropriate to analyse the rebate rate for the export product itself and not the VAT rebate rate that applies to intermediate inputs.

Which pollutants should be considered in the analysis? The NDRC's announcement does not tell us which pollutants the Chinese government targets with its policy. In order to gauge which pollutants play a prominent role in China's environmental agenda, we refer to the environmental section of the Chinese Five Year Plan (FYP). The Chinese FYP specifies China's goals and priorities in environmental protection and sets out specific pollution reduction targets for major pollutants. We expect that the set of pollutants K which determine trade policy is similar to the set of pollutants for which the government specifies emission reduction targets in the FYP.

The relevant FYPs for our sample period specify emission reduction targets for waste water, COD, ammonium nitrogen, soot, SO_2 and dust emissions as well energy use per unit of GDP (see Section 3.3.1). Moreover, China aims at reducing the amount of solid waste generated and at increasing the ratio of solid waste that is recycled. This indicates that the Chinese regulator's objective function puts weight on the above-mentioned pollutants and suggests that our analysis focuses on precisely those pollution indicators.[9]

When we analyse the relationship between trade policy and the pollution intensity of exports, we are interested in the overall pollution generated during all stages of the production process taking place within China. For example, the export tax for leather shoes should be based on the overall pollution content of leather shoes. This includes the direct pollution generated during the assembly of leather shoes as well as the indirect pollution generated during the production of leather. In order to obtain the overall pollution content of exports, it is necessary to use input-output analysis. The precise construction of overall pollution intensities is described in Section 3.6. The overall pollution intensity is measured as the overall pollution generated by an industry relative to the industry's output.

The theoretical model predicts that a higher pollution intensity has a stronger effect on the export tax if the gap between marginal damage and the pollution tax is larger. Hence, it is necessary to interact the pollution intensities with a measure for the gap between marginal damage and the pollution tax. As mentioned above, we use the share of emissions not meeting discharge standards as a proxy for this regulatory gap, *Reg_gap*, between the pollution tax and marginal damage. This measure varies at the industry level and over time. The share of emissions not meeting discharge standards is a useful measure of the regulatory gap since the national

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[9] Dust emissions will not be considered in the analysis. Due to a large number of missing observations it is not possible to generate the overall dust emission intensities.

authority can set discharge standards such that they internalize marginal damage. The enforcement is left to local authorities. If local enforcement is lax, firms have few incentives to satisfy discharge standards. Hence, a low ratio of emissions meeting discharge standards means that regulation is ineffective since it does not have a strong deterrent effect on emissions.

Data on the ratio of a pollutant meeting discharge standards is only available for waste water, soot and SO_2 emissions. For the remainder of the pollutants, we do not have any information about the gap between marginal damage and the pollution tax. However, as mentioned above, the Five Year Plans for the years 2000 to 2010 foresee reductions in the emissions of all pollutants in our analysis. The fact that the government intends to reduce emissions and sets targets for emission reductions indicates that the emissions are above the social optimum, which is equivalent to a situation in which the pollution tax is too lax.

With the pollution tax not internalizing the distortion to the desired extent, we would expect to see a positive relationship between the pollution intensity and the dependent variable y if the export taxes are a second best environmental policy. In other words, we expect the coefficient β_k in Equation 3.2 to be positive. We could infer that trade policy is not driven by environmental concerns if all the coefficient estimates $\hat{\beta}_k$ are equal to zero. An F-test allows us to test for the null-hypothesis that the coefficient estimates for the pollution intensities are all equal to zero.

The equation for the second-best export tax applies to the cross-section. Equation 2.28 demonstrates that the second-best export tax is higher for goods which are more pollution intensive at a particular point in time. A comparison of export taxes and pollution intensities between goods at one particular moment in time requires a cross-sectional analysis. Hence, our identification comes from variation in the cross section. Even though we have a panel dataset, we will not use product fixed effects. Since fixed effects eliminate cross-sectional variation, they are unsuitable for the purpose of our analysis.

We use the time-series dimension of the dataset to allow the coefficient estimates to vary across time. The Chinese government repeatedly linked trade policy to environmental concerns from 2007 onwards (see e.g. Wang et al., 2010). Since our dataset spans the years 2005 to 2009, we have information on trade policy and pollution intensities both before and after the policy announcement. Hence, the panel dimension of the dataset allows us to test whether there was a policy change in the years 2007 to 2009 compared to the years 2005 to 2006.[10]

If the VAT rebate rates and export tax adjustments from 2007 onwards were motivated by an attempt to reduce emissions of a particular pollutant k, we would expect the magnitude of the coefficient estimate $\hat{\beta}_k$ to increase in the 2007-2009 sample compared to the 2005-2006 sample. We will, thus, run two pooled cross-sectional regressions of Equation 3.2, one for the sample spanning the years 2005 to 2006 and one for the sample spanning the years 2007 to 2009. Moreover, we will test for a statistically significant difference in the coefficient estimates between the two sample periods. Towards that end, we interact all of the independent variables in our model with a dummy variable that takes the value of 1 for the years 2007 to 2009. Let that dummy variable be denoted by D_{2007} and let $\mathbf{X_{it}}$ denote the vector of independent variables. The vector $\mathbf{X_{it}}$ contains the pollution intensities, the resource dummy variables and the control variables. In order to test for statistically significant changes in the coefficient estimates, we estimate the model

$$y_{it} = \alpha_0 + \beta \boldsymbol{X_{it}'} + \gamma(\boldsymbol{X_{it}} * D_{2007})' + \delta_t + \epsilon_{it} \tag{3.5}$$

where β and γ are coefficient vectors and δ_t are year fixed effects. We use data for the entire sample period covering the years 2005 to 2009. A statistically significant coefficient estimate $\hat{\gamma}_l$ indicates that there is a change in the relationship between the explanatory variable X_l and the dependent variable y between the two sample periods.

If the coefficient estimate $\hat{\gamma}_k$ for the pollution intensity with respect to pollutant k is statistically significant and positive, this means that an increase in the pollution intensity of a particular pollutant k is associated with a larger increase in the overall export tax after 2007. This would suggest that the export tax or the VAT tax was adjusted to discourage pollution intensive production.

The dependent variable in our model varies at the HS8 digit level. However, data on pollution intensities are only observed at the industry level. In order to take account of the fact that our main explanatory variable varies at a higher level of aggregation, we cluster the standard errors at the industry level.[11]

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[10] This chapter of the thesis studies the factors which motivate the Chinese government to manipulate VAT rebates and export taxes. It is not concerned with the effect of the VAT rebate rates and export taxes on pollution. Therefore, we are not concerned that the sample period ends in 2009.

[11] Alternatively, one could aggregate the trade policy data to the industry level and conduct the analysis at the industry level. We find similar relationships between the overall export tax and the pollution intensities in the industry level data.

3.5.2 Control variables

The second-best export tax in Equation 3.2 features an environmental component as well as the terms of trade motive. This terms of trade motive depends on the foreign elasticity of import demand and is difficult to measure. However, the terms of trade motive reflects China's market size on the world market and is thus reflected in China's share in global exports. In order to control for the terms of trade motive, we use two dummy variables. The first dummy variable *Exp share* $[5-15)$ takes the value of 1 if China exports at least 5 percent and less than 15 percent of global exports. About 28 percent of the observations in our sample fall into this category. The second dummy variable *Exp share* 15+ takes the value of 1 if China exports more than 15 percent of global exports.[12] Another 32 percent of the observations in our sample fall into the latter category. Since the second-best export tax is larger for products for which China has market power, we expect the coefficient estimates for those dummy variables to be positive.

According to the NDRC, the VAT rebate adjustments are also geared towards reducing exports of resource-intensive products. In order to control for this aspect of policy setting, we introduce dummy variables that take the value of 1, if a product is resource intensive. We distinguish between four categories of resources: mineral products, wood products, precious stones and metal products. The resource dummy variables are constructed based on the HS classification. The dummy variable *Mineral* takes the value of 1 for all products in the HS2 digit categories 25 to 28. The range of products in these categories includes ores, mineral fuels and oil as well as rare earths. The dummy variable *Wood* takes the value of 1 for all wood products, articles of wood and wood charcoal (HS2 digit code 44). *Stones* is a dummy variable for all products in the HS2 digit category 71. This includes precious metals, precious stones, pearls and jewellery. The dummy variable $Metal$ takes a value of 1 for all metal products in the HS2 digit categories 72 to 81, including iron and steel, copper, aluminium, lead, zinc, tin and articles thereof. We expect a positive relationship between the VAT tax or the export tax and the resource dummy variables if the trade policy reforms are a substitute for resource conservation.[13]

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[12] The categories were chosen such that each category contains roughly the same number of observations. In other words, about a third of the products are classified such that China has no market power, another third falls into category $[5-15)$ and another third falls into category 15+.

[13] Resource intensity can also be defined as resource use relative to value added. A

Note that the resource dummy variables include both primary products and processed products. The dummy variable $Wood$ for example, takes a value of 1 for raw logs as well as wooden furniture. Hence, the resource dummy variables do not measure whether the government protects primary products more than raw materials.

The complainants in the WTO dispute settlement case on rare earths argue that China introduced export restrictions on raw materials in order to grant downstream producers in China protected access to those raw materials (WTO, 2014). In order to test for this hypothesis, we add a dummy variable to the regression which takes the value of 1 if a product is classified as a primary product according to the United Nation's Classification of Broad Economic Categories.[14] A positive coefficient estimate for this variable would suggest that the export restrictions target primary products. This could provide an incentive for downstream producers to relocate to China where the primary products are available at a lower price.

Our model assumes that the government acts as a welfare maximizer. However, this assumption might be too restrictive in the real world. The literature on the political economy of protection highlights alternative motives that can drive the government's choice of trade policy.[15] The theories in the literature on the political economy of protection that are most closely related to the notion of a welfare-maximizing regulator in our model are the theories which suggest that the government has social concerns in mind when it sets trade policy. Social considerations might be particularly important in China, since the Chinese government tries to maintain a certain level of social stability. This is reflected in recent attempt

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product?s resource intensity could be calculated using input-output analysis or life-cycle analysis. However, there are several downsides to calculating resource intensity using Chinese data. Firstly, we lack information on value added. Secondly, Chinese input-output tables are only produced every 5 years and do not reflect developments in the economy. Thirdly, the use of input-output analysis requires assumptions such as the import proportionality assumption. Finally, the measure would only be available at the level of aggregation at which Chinese input-output tables are available. The HS classification allows us to create the measure at the product level.

[14] Details on the Broad Economic Categories are available on `http://unstats.un.org/UNSD/cr/registry/regcst.asp?Cl=10&Lg=1`

[15] A large literature argues that protection is granted in exchange for political support (e.g. Caves, 1976; Grossman and Helpman, 1994). The most prominent model in this literature is the 'protection for sale' model by Grossman and Helpman (1994), which assumes that industries lobby for protection if they manage to overcome a free-rider problem. Grossman and Helpman (1994)'s model has received considerable attention in the literature that analyses the determinants of trade policy in the U.S. However, it is not obvious that the model can be applied to China. China does not have democratic elections and lobbying is not officially allowed. Moreover, none of the measures for lobbying power which are typically used in that literature is available for China.

to build a "harmonious society" and reduce inequality within the country. Corden (1974) links trade policy to social concerns. In Corden (1974), the regulator has a conservative welfare function and grants protection to industries which suffer from adverse economic shocks. This would suggest that protection is higher, and hence the VAT tax or the export tax is lower, in industries in which output growth is lower. Therefore, we control for output growth compared to the previous year.

Even though the Chinese government does not face any elections, we can still assume that it tries to gain popular support for its policies in order to consolidate its power. This is the reason why models like the adding machine model by Caves (1976) apply to China. According to the adding machine model, politicians protect industries which represent the largest number of voters. The model predicts a positive relationship between the number of employees in an industry and protection. In a similar vein, industries with a larger number of firms could receive higher protection. We control for both, the employees and the number of firms in an industry.

An important control variable is the share of state-owned enterprises in an industry. State-owned enterprises are likely to have links to the government which allow them to lobby for protection. Branstetter and Feenstra (2002) show that the Chinese government gave between four and seven times more weight to SOEs than to consumer welfare in the context of policies that facilitate foreign direct investment. This suggests that SOEs have a significant influence on government decisions which might also be reflected in China's trade policy. Moreover, Wang and Xie (2010) provide support for the hypothesis that Chinese trade policy protects SOEs in showing that the VAT rebates are lower for firms with a higher share of national capital. Since it is likely that protection is higher in industries with more state-owned enterprises, we control for the output share of state owned enterprises in an industry, measured as the output value of SOEs relative to the output value in the industry.

In a similar vein, the Chinese government might try to grant foreign firms better treatment in order to enhance the investment climate in China. This would imply that industries with a higher share of foreign output get higher protection. Since foreign firms might use less polluting production technology, it is important to control for the output share of foreign firms. The output share of foreign firms is measured as the output value of foreign firms relative to the overall output value in an industry.

Several authors argue that protection should be higher in industries for which the country does not have a comparative advantage (e.g. Ray, 1981a,b; Trefler, 1993). As a country with an abundant labour supply, China is traditionally associated with a comparative advantage in labour-intensive industries (Yue and Hua, 2002). Hence, the VAT tax or export tax might be higher in labour-intensive industries. We, thus, control for the labour intensity which is constructed as the number of employees over fixed assets in an industry. If the government protects industries in which it does not have a comparative advantage, the protection could also be expected to be higher in export-intensive industries. The export intensity is measured as the value of exports relative to the output value.

The choice of the VAT rebate rate could also be driven by concerns about government revenue. Evenett et al. (2012) show that expenses for VAT rebates constitute 8 to 10 percent of final government spending between 2007 and 2010. The theoretical model presented in Section 3.4 incorporates the revenue generated by trade policy in the regulator's welfare maximization problem. Hence, there is no need to add a control for government revenue if we implement Equation 3.2. If the government is concerned about the effect of the policy on its budget, it might, however, take income taxes from firms into consideration. A higher VAT tax or export tax can be expected to lead to a contraction of the industry and reduce taxes that firms have to pay on their business. Hence, the government might set a lower VAT tax or export tax for industries which pay a higher tax on their principal business. We control for this motive using the firms' income tax as a control variable.

Some of the above-mentioned control variables may be endogenous if we use the contemporaneous value. It is possible that an increase in the export tax or a reduction the VAT rebate reduce China's export share on the world market or the number of firms and employees in an industry. Moreover, trade policy may affect output growth in an industry or the industry's profitability. In order to avoid reverse causality, we use the lagged value of the control variables.[16]

We also include the ad valorem tariff as an independent variable. The tariff might be determined by the same factors as the export tax and the VAT tax. Moreover, protection on the import side might be used as a substitute for protection on the export side and hence the tariff and protection on the export side might be related. Omitting the tariff as a control variable could thus bias the results.

A complete list of variables used in the analysis as well as the variable

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[16] This does not affect the coefficient estimates for the pollution intensities. We get very similar results if we use the contemporaneous value of the control variables.

definition and the expected sign of the coefficient estimates is available in Table 3.2.

3.6 The dataset

3.6.1 Trade policy data

Trade policy variables used for the analysis include VAT rebates, export taxes and import tariffs.

For the construction of the dependent variable VAT tax, we gather data on VAT and VAT rebate rates at the product level (HS10 digit). The VAT data are from the China Customs homepage[17] and from the Customs Import and Export Tariff of the People's Republic of China.

The dataset on VAT rebate rates is constructed based on information from the China Customs homepage, from the homepage of the State Administration of Taxation[18] or from the Ministry of Finance[19]. The China Customs homepage offers information on VAT rebate rates for all tariff lines (at the HS10 digit level) for the years 2005 to 2006. From 2006 onwards, we only have information on changes in export VAT rebate rates. The information on rebate rate reforms is used to update the VAT rebate rate schedule for all tariff lines for the years 2007 to 2009. A list of reforms can be found in Table 3.18 in the Appendix.

In 2007 there was an international reclassification of HS tariff lines. This also affects the Chinese tariff lines. To the best of our knowledge, there is no concordance table at the HS8 or HS10 digit level that relates Chinese tariff lines prior to 2007 to tariff lines from 2007 on. Concordance tables only exist at the HS6 digit level. Since we cannot link the tariff lines before and after the reclassification, we only use the VAT rebate rates for tariff lines which were not affected by the reclassification. This should not bias our results, since the HS reclassification at the HS6 digit level is undertaken by the World Customs Organization and not by the Chinese government itself.

Information on export taxes at the product level (HS10 or HS11) for the years 2005 to 2007 is available on the China Customs homepage. The homepage of the Ministry of Finance provides export tax data at the HS8

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[17] `http://china-customs.com/`

[18] `http://www.chinatax.gov.cn/`

[19] `http://szs.mof.gov.cn/zhengwuxinxi/zhengcefabu/200808/t20080801_60216.html`

Table 3.2: Variable definition

Variables	Description	Expected sign
VAT tax	VAT minus export VAT rebate	
Export tax	Defined as ordinary export tax or temporary export tax	
Overall export tax	Export tax + VAT tax	
Water Reg_gap*Int	Interaction term of waste water emissions not meeting discharge standards with the overall waste water intensity (in tons/million yuan output. The output value is deflated using the manufacturing producer price index)	+
COD Int	Overall COD intensity (tons/million yuan output)	+
Ammonium N. Int	Overall Ammonium Nitrogen Intensity (tons/million yuan output)	+
Soot Reg_gap*Int	Interaction term of the ratio of soot emissions not meeting discharge standard with the overall soot intensity (in tons/million yuan output)	+
SO2 Reg_gap*Int	Interaction term of the ratio of SO2 emissions not meeting discharge standards with the overall SO2 intensity (in tons/million yuan output)	+
Waste Int	Overall waste intensity (tons/million yuan output)	+
Recycling Ratio	Overall solid waste utilized/overall solid waste generated	-
Energy Int	Overall energy intensity (tons of SCE/million yuan output)	+
Mineral	Dummy variable for mineral products in the HS2 categories 25 to 27.	+
Metal	Dummy variable for metal products in the HS2 categories 72 to 81.	+
Wood	Dummy for wood products in HS2 category 44.	+
Stones	Dummy for precious stones in HS2 category 71.	+
Primary	Dummy variable for primary products	+
Exp share [5-15)	Dummy variable, 1 if China's export relative to global exports are between 5 and 15 percent.	+
Exp share 15+	Dummy variable, 1 if China exports are at least 15 percent of global exports.	+
Employees	Employees (in millions)	-
Firm No	Number of firms in the industry (in thousands)	-
Profits	Industry profits (in billion yuan)	-
Δ Output	Output growth compared to the previous year	+
Labour Intensity	Employees/million fixed assets in the industry	+
Export Intensity	Exports in an industry/industry output	+
SOE share	Output share of state-owned enterprises	-
Foreign share	Output share of foreign enterprises	-
Income tax	Taxes and other charges on firms' principal business (billion yuan)	-
Tariff	Applied MFN Tariff	?

digit level for the years 2008 to 2009.

During our sample period there are different kinds of export taxes: ordinary export taxes and a temporary export taxes. The ordinary export tax applies as long as there is no temporary export tax. Our export tax variable is thus defined as the ordinary export tax. If a temporary export tax is implemented, the export tax variable takes the value of the temporary export tax.

Data on import tariffs are from the WITS TRAINS database. We use the information on applied most favoured nation (MFN) tariffs. The TRAINS data are available at the HS8 digit level. As for the rebate rates, we only use information on the tariff lines that are not affected by the reclassification and exist throughout the sample period.

3.6.2 Environmental data

The China Statistical Yearbook on Environment provides information on water pollution, air pollution and solid waste at the industry level. Data on energy consumption at the industry level are available in the China Statistical Yearbook. The Chinese industry level data distinguish between 40 industry sectors. These sectors include mining, manufacturing as well as production and supply of electricity, gas and water. However, there is no trade in the sectors *Production and Supply of Gas* and *Production and Supply of Water*. Hence, these sectors do not appear in our analysis. A list of industries in our dataset in available in the Appendix in Table 3.16.

While the data provide information on the *level* of pollution in a particular industry, we are interested in pollution *intensities*. To obtain the pollution intensities, we scale emissions by the output value of a sector in a given year. The information for the output value at the industry level is available in the Industry Chapter of the China Statistical Yearbook and we deflate the output value using the manufacturing producer price index from the China Statistical Yearbook.

As suggested in Section 3.5, it is necessary to work with the pollution embodied in China's exports rather than the pollution generated by each industry sector. The pollution intensity of China's exports can be obtained using input-output analysis.

Input-output analysis makes use of the condition that the supply of N goods, $S_{[Nx1]}$, equals the demand for those N goods.[20] The demand can be

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[20] See e.g. Miller and Blair (1985). Milner and Xu (2009) use input-output analysis to study the pollution content of China's trade.

expressed as $A_{[NxN]}S_{[Nx1]} + Y_{[Nx1]}$ where A is the matrix of input coefficients a_{ij}. The input coefficients a_{ij} represent the inputs of commodity i needed to produce commodity j. AS is the amount of goods that are used as intermediate inputs for production and Y is final demand. Final demand Y consists of domestic consumption Y^D, imports Y^M and exports Y^X, i.e. $Y = Y^D + Y^M + Y^X$. Supply equals demand if $S = AS + Y$. Solving for S, yields

$$S = (I - A)^{-1}Y \tag{3.6}$$

where $(I - A)^{-1}$ is the Leontief inverse. The element c_{ij} of the Leontief inverse represents the amount of units of input i which is needed for the production of output good j. An increase in exports of good j by one unit thus requires c_{ij} additional units of good i as intermediate input.

To obtain the overall pollution intensities, we use the matrix of emission intensities $E_{[MxN]}$ whose elements e_{ki} denote emissions of pollutant k caused during production of one unit value of good i. Multiplying Equation 3.6 with the matrix of emission intensities, the emissions generated during production are related to the emissions embodied in exports through the following relationship:

$$ES = E(I - A)^{-1}Y \tag{3.7}$$

The matrix $E(I-A)^{-1}$ represents the overall pollution intensity. Its elements tell us how much additional pollution is generated for an additional unit of final demand (which includes exports).

In order to obtain the overall pollution intensity, we need the direct pollution intensity E and the Leontief inverse $(I-A)^{-1}$. The direct pollution intensities in matrix E are obtained by dividing the pollution emissions of a sector by the value of output. The Leontief inverse can be derived using the Chinese input-output (IO) table. We use the most disaggregate Chinese input-output table which contains 135 sectors ranging from agriculture and manufacturing to services. The disaggregate input-output tables are only produced every 5 years. We use the table for 2007.[21]

Chinese IO tables treat all imports as final deliveries. Since this is not in line with the real world experience, we follow Milner and Xu (2009); Hummels et al. (2001) and Feenstra and Hanson (1999) and use the import

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[21] Since we only use one input-output table, we implicitly assume that the input-output coefficients are constant over time. This assumption is unlikely to hold in a rapidly growing economy such as China in the 2000s. However, there is no alternative to these input-output tables. Even though the input-output coefficients are considered constant, the direct pollution intensities change. This mean that we can capture some of the changes in production technologies and abatement costs.

proportionality assumption. We assume that imports and domestically produced goods within a sector are perfect substitutes and that the same proportion of the sector's output is used as intermediate input irrespective of whether the output is produced domestically or imported. In order to implement the import proportionality assumption we have to use an adjustment matrix. Let q_i be defined as $q_i = \frac{Gross\ Output_i}{Gross\ Output_i + Imports_i}$ where $Gross\ Output_i$ is the gross output of industry i and $Imports_i$ are the imports of industry i. The adjustment matrix D is a diagonal matrix with the values q_i on its diagonal. Using the adjustment matrix, the Leontief inverse is given by $(I - DA)^{-1}$.

The input-output table is slightly more disaggregated than the industry classification in the environmental data. Hence, it is necessary to aggregate the IO table to the industry level for which we have environmental data. We then calculate the input-output coefficients and the adjusted Leontief inverse for the aggregate table.

Note that the input-output table includes information on agricultural and service sectors. However, there are no corresponding emission data for these sectors. Hence, we aggregate all of these sectors into one sector and delete the respective row and column from the IO table. This has to be taken into account when we interpret the overall pollution intensities (OPIs). The OPI represents the total pollution generated by a final product and all its manufacturing inputs. It does not include the pollution generated by intermediate outputs from agricultural and service sectors.

3.6.3 Industry level control variables

The information on the number of employees, the number of firms in an industry, output growth compared to the previous year, the output shares of SOEs and foreign firms, profits, the capital intensity and the income tax is from the industry chapter of the China Statistical Yearbook. The export intensity variable is constructed using data on the trade volume from the BACI trade database. Since the BACI trade data are denoted in US$, we use the average annual exchange rate from the China Statistical Yearbook to obtain the volume of exports in RMB. This export volume is divided by the output value to obtain the export intensity.

3.6.4 Concordance tables

Our data set contains variables from different data sources at different levels of aggregation. We aggregate the VAT, VAT rebate and the export tax data to the HS8 digit level and merge it with the tariff line data from the WITS. In order to merge the trade data and the environmental data, we use two concordance tables. The first concordance table links the HS8 digit tariff lines to the sectors in the Chinese Input-Output table for 2007. The concordance table is available in the appendix of the Chinese input output table for 2007. The second concordance table links the relevant sectors from the input-output table to the 40 industry sectors for which we have environmental data. The sectors of the Chinese input-output table approximately follow the Chinese industry classification GB/T4754-2002. Hence, the concordance table is constructed manually based on the subcategories of the description of the Chinese industry classification system.

3.7 Summary statistics

This section provides summary statistics for all trade policy variables, pollution intensities and the control variables. Table 3.3 provides means and standard deviations. Table 3.4 allows us to track the changes in the means of all variables over time.

The summary statistics in Table 3.3 show that the average difference between the VAT and the export VAT rebate (variable *VAT tax*) is 5.9%. The average VAT tax increases from 4.4% in 2005 to 7.9% in 2008 and falls to 6% in the aftermath of the economic and financial crisis (see Table 3.4).

The average export tax increases from 0.09 in 2005 to 0.65 in 2009. This increase in the average export tax is due to an increase in the scope of the export tax. The last row of Table 3.1 shows that the average export tax for products which are subject to a positive export tax falls from 18.5% in 2005 to 16% in 2009.

Table 3.4 shows that the pollution intensity for all pollutants declines over the sample period. The decline in the pollution intensity is gradual and does not seem to be affected by the introduction of export taxes and the increase in VAT rebate rates in 2007. This should ease concerns about reverse causality between trade policy instruments and the pollution intensities.

In levels, waste water, solid waste and energy use increase in the course of the sample period. However, output grows faster than emissions.

Table 3.3: Summary statistics

	(1)			
	mean	sd	min	max
VAT tax	5.986	4.585	0.00	17.00
Export tax	0.358	2.716	0.00	40.00
Tariff	9.724	7.105	0.00	65.00
Water Int	1808.262	1434.616	138.96	13212.33
Water Stand_Rat	0.939	0.038	0.78	0.99
COD Int	0.372	0.525	0.02	5.49
Ammonium N. Int	0.027	0.029	0.00	0.19
Soot Int	0.522	0.337	0.03	4.03
Soot Stand_Rat	0.876	0.085	0.50	1.03
SO2 Int	1.369	0.698	0.10	11.43
SO2 Stand_Rat	0.855	0.079	0.12	1.00
Waste Int	135.034	132.973	15.46	1906.15
Recycling Ratio	0.616	0.093	0.18	0.79
Energy Int	147.527	66.430	14.07	360.95
Mineral	0.063	0.243	0.00	1.00
Metal	0.084	0.278	0.00	1.00
Wood	0.011	0.105	0.00	1.00
Stones	0.011	0.102	0.00	1.00
Primary	0.054	0.226	0.00	1.00
Exp share [5-15)	0.287	0.452	0.00	1.00
Exp share 15+	0.337	0.473	0.00	1.00
Employees	3.056	1.825	0.04	6.77
Firm No	15.135	9.997	0.15	37.37
Profits	76.366	65.276	-100.31	460.12
Δ Output	1.260	0.166	0.71	3.68
Labour Intensity	11.475	8.045	0.65	46.46
Export Intensity	0.000	0.002	0.00	0.14
SOE share	0.204	0.205	0.00	0.99
Foreign share	0.299	0.144	0.00	0.84
Income tax	15.445	31.734	0.12	241.76
Output Value	15569.930	10232.987	292.95	44727.96
Observations	28742			

Table 3.4: Summary statistics by year

	(1) 2005	(2) 2006	(3) 2007	(4) 2008	(5) 2009
VAT tax	4.407	4.871	6.755	7.899	5.997
Export tax	0.093	0.128	0.294	0.629	0.651
Tariff	9.938	9.758	9.876	9.551	9.492
Water Int	2425.646	2023.989	1760.782	1522.497	1301.721
Water Stand_Rat	0.939	0.938	0.931	0.932	0.955
COD Int	0.561	0.441	0.354	0.274	0.227
Ammonium N. Int	0.052	0.032	0.022	0.016	0.013
Soot Int	0.853	0.636	0.475	0.358	0.286
Soot Stand_Rat	0.843	0.860	0.885	0.872	0.919
SO2 Int	1.910	1.622	1.317	1.087	0.903
SO2 Stand_Rat	0.798	0.835	0.853	0.887	0.901
Waste Int	157.862	142.115	134.757	124.984	115.189
Recycling Ratio	0.572	0.588	0.609	0.637	0.676
Energy Int	176.180	160.187	141.520	134.938	124.507
Exp share [5-15)	0.262	0.286	0.292	0.300	0.294
Exp share 15+	0.290	0.318	0.343	0.359	0.375
Employees	2.666	2.831	3.026	3.387	3.372
Firm No	11.538	12.882	14.425	18.271	18.609
Profits	39.745	51.583	82.295	88.195	120.604
Δ Output	1.384	1.266	1.291	1.262	1.095
Labour Intensity	13.788	12.625	11.593	10.359	8.974
Export Intensity	0.000	0.000	0.000	0.000	0.000
SOE share	0.234	0.215	0.203	0.189	0.179
Foreign share	0.308	0.309	0.309	0.295	0.272
Income tax	7.294	8.912	11.959	15.455	33.857
Output Value	9604.670	12076.022	15534.552	19540.003	21171.487
Observations	5758	5769	5771	5759	5685

The summary statistics also reveal that compliance with environmental regulation increases over time. Table 3.4 shows that the ratio of soot emissions meeting discharge standards increases from 84 percent in 2005 to 94 percent in 2009. The ratio of SO_2 emissions meeting discharge standards increases from 80 percent in 2005 to 90 percent in 2009. This means that the gap between marginal damage and the pollution tax declines.

Relationship between the overall export tax and the pollution intensities

Prior to the analysis of our results, we look at the relationship between the overall export tax and the pollution intensities in the raw data.

Figure 3.1 plots the development of the average overall export tax from 2004 to 2009 for the two pollution-intensive industries *Paper* and *Non-metallic Mineral Products* against the overall export tax of the relatively clean industries *Articles for Culture/Education* and *Manufacture of Communication Equipment.*

Paper Production is the most water, COD and ammonium nitrogen intensive industry in 2007.[22] The average overall export tax for *Paper Production* is close to 15 percentage points at the beginning of the sample period. In 2008, it increases to more than 26 percentage points. This increase in the overall export tax is due to an increase in the average export tax from 0 to 10 percent in 2008. The VAT tax increases slightly to 16 percentage points in 2008.

The graph also shows the average overall export tax for *Non-metallic Mineral Products.* The latter is the second most soot, SO_2 and energy intensive industry. The average overall export tax for *Non-Metallic Mineral Products* is 4 percent in 2004. From 2006 on, it increases gradually and reaches 12 percentage points in 2008. A surge in the overall export tax for a pollution intensive industry from a very low level could represent an adjustment towards an environmentally motivated overall export tax.

The industries *Articles for Culture/Education* and *Communication Equipment* have low pollution intensities across almost all of the pollutants. The overall export tax for *Communication Equipment* declines over the sample period and the overall export tax for *Articles for Culture/Education* increases less than the overall export tax for the clean industries.

From 2007 on, the average overall export tax for the two clean industries

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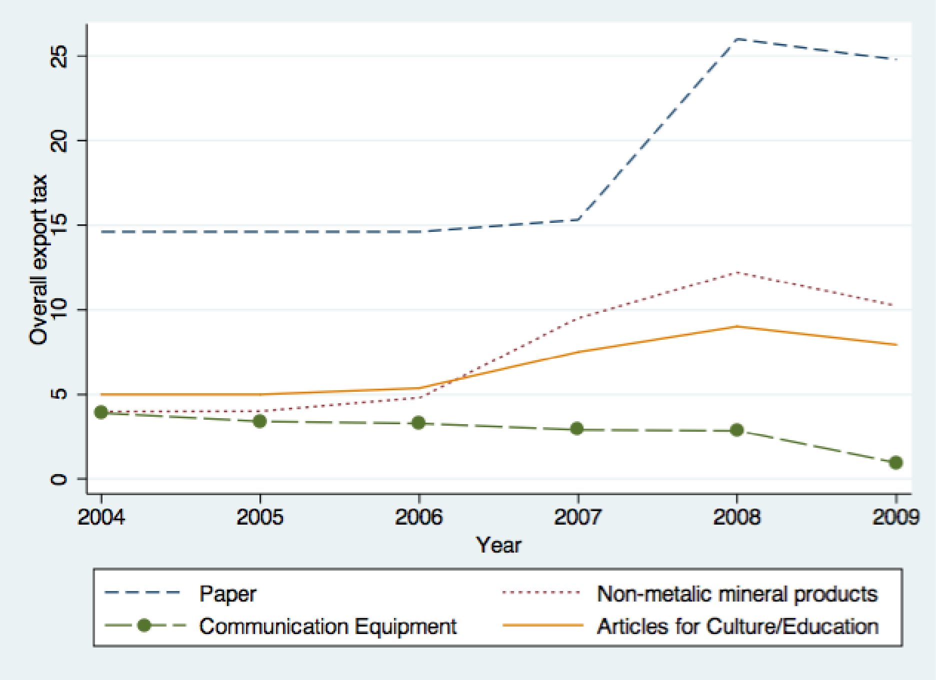
[22] See Table 3.21 in the Appendix. The table ranks industries according to their pollution intensities. A higher rank indicates that the product is more polluting.

Figure 3.1: Development of the average overall export tax for several industries



is lower than the overall export tax for the polluting industries. We would expect this pattern if the overall export tax was motivated by environmental concerns. As a consequence of the adjustments in the overall export tax, the incentive to produce relatively clean goods increases whereas the incentive to produce polluting goods declines. The VAT rebate and export tax adjustment could thus lead to a reallocation of resources from pollution intensive industries to clean industries. As a result, the overall pollution intensity of production could decline.

The correlation Table 3.19 in the Appendix gives a first impression of the correlation between the overall export tax and the pollution intensities. The correlation between the overall export tax and the pollution intensities should be positive, if the government uses export taxes and VAT rebates as a second-best policy instrument to reduce pollution. Table 3.19 demonstrates that the overall export tax is significantly positively correlated with the waste water intensity, the COD intensity and the SO_2 intensity. Moreover, the solid waste intensity and the energy intensity are positively correlated with the VAT tax.

3.8 Results

This section presents our empirical results. Section 3.8.1 explains our findings for the determinants of the overall export tax. We explore the relationship between the export tax and the VAT tax in Section 3.8.2. The results for regressions using the export tax and VAT tax as dependent variables are explained in Section 3.8.3 and Section 3.8.4 respectively.

3.8.1 Overall export tax as a dependent variable

Table 3.5 displays the results for a cross-sectional analysis of model 3.2 with the overall export tax as dependent variable. Column 1 of Table 3.5 shows the relationship between the overall export tax and the pollution intensities as well as the control variables for the years 2005 to 2006. The relationship between the pollution intensities and the overall export tax for the year 2007 to 2009 is displayed in Column 2 of Table 3.5. The third column of the table indicates whether there is a statistically significant difference between the coefficient estimates for the 2005-2006 sample and the coefficient estimates for the 2007-2009 sample. In order to test for a statistically significant difference in the coefficient estimates, we run the regression presented in Equation 3.5. Column 3 of Table 3.5 shows whether the the coefficient estimates for the interaction term of regressor X_l with the dummy variable D_{2007} is statistically significant.

The results suggest that the pollution intensities are a significant determinant of the overall export tax. An F-test demonstrates that the coefficient estimates for the pollution intensities as well as the energy intensity are jointly significant in both sample periods.

Concerns about water pollution seem to be one motive for the adjustments in the overall export tax. The statistically significant positive coefficient estimate for Water Reg_gap*Int in Column 2 of Table 3.5 demonstrates that there is a positive relationship between the overall export tax and the overall waste water intensity (interacted with the share of emissions not meeting discharge standards) from 2007 onwards. This is in line with our expectations if the overall export tax is motivated by concerns about waste water discharge from 2007 on.[23]

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[23] The results for the relationship between the overall export tax and the pollution intensities are not driven by our control variables. Table 3.20 in the Appendix shows the results for an unconditional correlation between the overall export tax and the pollution intensities. The significance patterns are similar to the the results presented in Table 3.6. One notable difference is the coefficient estimate for the ammonium

Table 3.5: Dependent variable: Overall export tax

	(1) 2005-2006	(2) 2007-2009	(3) Difference
Water Reg_gap*Int	−0.000	0.013**	**
	(0.002)	(0.005)	
COD Int	2.064***	−1.634	**
	(0.437)	(1.279)	
Ammonium N. Int	−1.012	50.258**	**
	(5.185)	(22.880)	
Soot Reg_gap*Int	−2.492	−3.902	
	(1.658)	(6.432)	
SO2 Reg_gap*Int	1.029	0.825	
	(0.826)	(1.718)	
Waste Int	0.004***	0.004	
	(0.001)	(0.003)	
Recycling Ratio	4.347**	12.884**	*
	(2.005)	(5.014)	
Energy Int	−0.001	0.033***	***
	(0.004)	(0.009)	
Mineral	2.295***	7.906***	***
	(0.531)	(0.826)	
Metal	2.300	6.932***	***
	(1.565)	(2.119)	
Wood	6.173***	6.271***	
	(0.722)	(0.942)	
Stones	2.407	3.334***	
	(1.754)	(1.188)	
Primary	2.333***	2.482*	
	(0.744)	(1.281)	
L.Exp share [5-15)	−0.123	−0.429	
	(0.212)	(0.269)	
L.Exp share 15+	0.075	0.242	
	(0.351)	(0.502)	
L.Employees	−0.061	−0.616**	*
	(0.200)	(0.268)	
L.Firm No	−0.096	−0.120**	
	(0.069)	(0.052)	
L.Profits	0.005	0.005	
	(0.006)	(0.005)	
L.Δ Output	2.537***	7.823*	
	(0.711)	(4.577)	
L.Labour Intensity	0.012	0.045	
	(0.016)	(0.057)	
L.Export Intensity	3.221	−6.481	
	(24.813)	(36.773)	
L.SOE share	−6.301***	−11.228***	
	(1.654)	(3.691)	
L.Foreign share	−1.908	−1.070	
	(1.286)	(2.643)	
L.Income tax	0.086***	0.111**	
	(0.030)	(0.044)	
Tariff	−0.042*	−0.068*	
	(0.022)	(0.036)	
Observations	11373	16954	
r2	0.370	0.535	
F	337.259	1200.954	

Cluster robust standard errors in parentheses. Column 3 indicates whether there is a statistically significant difference in the coefficient estimates for the 2007-2009 sample compared to the 2005-2006 sample. No entry means that there is no statistically significant difference. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

The coefficient estimate for the waste water intensity indicates that the overall export tax increases by 0.013 percentage points as the waste water intensity increases by 1 ton per million yuan output. In order to assess whether the magnitude of the coefficient estimate is economically meaningful, we calculate the predicted change in the overall export tax that results from an increase in a product's pollution intensity with respect to pollutant k from the 25th percentile to the 75th percentile. The predicted change in the overall export tax is displayed in Table 3.6.

Table 3.6: Predicted change in the overall export tax

	(1) Before 2007	(2) From 2007 on
Water Reg_gap*Int	-0.006	0.962
COD Int	0.785	-0.407
Ammonium N. Int	-0.030	0.691
Soot Reg_gap*Int	-0.248	-0.128
SO2 Reg_gap*Int	0.194	0.097
Waste Int	0.477	0.367
Recycling Ratio	0.614	1.670
Energy Int	-0.067	2.576
Observations	11373	28327

Change from the 25th percentile to the 75th percentile

Table 3.6 shows that a jump in the waste water intensity from the 25th to the 75th percentile would lead to an increase in the overall export tax of 0.96 percentage points in the 2007-2009 sample.

Moreover, the export tax and VAT rebate adjustments could also be aimed at reducing ammonium nitrogen emissions. The overall export tax is significantly higher for ammonium nitrogen intensive products from 2007 on, hence discouraging exports of those products. The overall export tax is predicted to increase by 0.69 percentage points as the ammonium nitrogen intensity increases from the 25th to the 75th percentile.

Despite the evidence that the VAT taxes discourage water pollution intensive exports, the COD intensity does not seem to be a significant determinant of the VAT tax in the 2007 to 2009 sample. This result could be due to the high correlation between the waste water intensity and the COD intensity. Table 3.19 in the Appendix shows a correlation coefficient of 0.92 between the two variables. It is, thus, possible that the COD intensity does not affect the VAT tax once we control for the waste water intensity.

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nitrogen intensity, which is statistically significant and negative if we do not control for other motives which influence trade policy choices.

Furthermore, the data support the Chinese authorities' claim that the VAT rebate and export tax adjustments aim at reducing energy consumption. The overall export tax is significantly higher for energy-intensive products from 2007 onwards. Based on our coefficient estimates, the overall export tax is 2.58 percentage points higher for a product with an energy intensity at the 75th percentile than for a product with an energy intensity at the 25th percentile, ceteris paribus (see Table 3.6). This difference is economically meaningful. Table 3.6 also shows that differences in the energy intensity can explain more of the difference in the overall export tax than differences in the pollution intensity with respect to any other pollutant k. The Chinese government seems to be most concerned about China's energy consumption when it chooses the overall export tax.

The results for our baseline regression in Table 3.5 do not indicate that the overall export tax is set in a way that discourages exports of soot or SO_2 intensive products. The respective coefficient estimates are not statistically significant. Since the 11th FYP for the years 2006 to 2010 does not include a target to reduce soot emissions, it is not surprising that the overall export tax is not significantly positively correlated with the soot intensity.

Moreover, the adjustments are unlikely to reduce the generation of solid waste. The overall export tax is significantly positively related to the solid waste intensity before 2007, but not from 2007 on. While the 10th FYP for the years 2000 to 2005 includes a target to reduce the generation of solid waste by 10 percent, there is no target for solid waste in the 11th FYP. This could explain the finding, that the overall export tax discourages exports of solid waste intensive products in the 2005 to 2006 sample but not in the 2006 to 2010 sample.

There is evidence that the overall export tax is higher for industries which recycle a larger share of their solid waste. This is opposed to our expectations. If the overall export tax was meant to reduce exports in industries which recycle only a small proportion of their solid waste, we would expect a negative relationship.

The fact that the coefficient estimates do not reflect an attempt to encourage recycling is not surprising if we look at China's environmental achievements in the 10th FYP. China planned to recycle 50 percent of its solid waste in the 10th FYP period. This target was overachieved with a recycling ratio of 56% (State Council of People's Republic of China, 2006). This indicates that domestic instruments might suffice to increase recycling and that the use of trade policy as a second-best policy instrument is not necessary.

Moreover, the results support the claim that the export tax and VAT rebate adjustments are meant to contribute to the conservation of China's natural resources. In the period from 2007 on, the overall export tax for mineral and wood products is estimated to be 7.9 and 6.3 percentage points higher than the overall export tax for other products, respectively. The export tax for precious stones and metal products exceeds the export tax for other products by 3.3 and 6.9 percentage points respectively. The conservation of resources seems to be an important motive behind China's trade policy especially when we compare the magnitude of the coefficient estimates for the resource dummy variables to the predicted changes in the overall export tax as a consequence of changes in the pollution intensity.

Furthermore, there is evidence that export taxes are consistent with an attempt to grant downstream producers in China protected access to raw materials. The coefficient estimate for the variable *Primary* suggest that the overall export tax on primary products is 2.3 percentage points larger than the export tax for other products prior to 2007. From 2007 on, exports of primary products are taxed 2.5 percentage points more than exports of other products. Since an export tax raises the price of primary products for downstream producers which are located abroad, the structure of the overall export tax may generate an incentive for downstream producers to relocate to China where the inputs are available at a lower price. The result that the overall export tax is higher for primary products is in line Garred (2014). He finds that the joint export tax equivalent of the VAT rebates and the export taxes increased faster for primary products over the period from 2002 to 2012.

As a large producer on the world market, China could introduce export taxes in order to manipulate the terms of trade in its favour. This would be reflected in a positive coefficient estimate for the dummy variables *L.Exp share* $[5-15)$ and *L.Exp share* 15+, which capture the share of Chinese exports in global exports in the previous period. The findings in Table 3.5, however, show that the export tax is not significantly related to China's share in global exports. Hence, there is no evidence that the overall export tax reflects an attempt to raise the world market price for Chinese exports.

The sign of the coefficient estimates for the remainder of the control variables is largely in line with our expectations. Industries with a larger output share of state-owned enterprises face a significantly lower overall export tax. The finding indicates that links between the government and

SOEs lead to a preferential treatment of industries in which SOEs produce a large proportion of the output value.

Furthermore, the Chinese government seems to grant more protection to large industries. The overall export tax is significantly lower for industries with a larger number of employees and a larger number of firms in the period from 2007 on. Industries which grow faster are less protected in the sense that the overall export tax on their exports is higher.

3.8.2 Relationship between export tax and export VAT rebate

Having discussed the results for the overall export tax as a dependent variable, we can now zoom in and analyse the determinants of the export tax and the VAT tax individually.

Before we start the discussion of our results, we investigate the relationship between the two instruments in more detail. As pointed out previously, China committed to eliminating its export taxes for all but 84 HS8 digit products when it joined the WTO. For each of these 84 products, the Accession Protocol lists a specific duty rate, which China is not allowed to exceed. This duty rate ranges between 20% and 40%. If the Chinese government has already implemented the maximum export tax allowed under the WTO Accession Protocol but wants to reduce exports further, it can resort to manipulating export VAT rebates.

The data suggest that the Chinese government exploits the VAT rebate rate as an instrument to reduce exports before it implements export taxes which violate its obligations under the WTO Accession protocol. The average rebate rate is zero for all but 15 products for which the export tax is positive and equal to or higher than the export tax allowed under the WTO Accession Protocol. However, the rebate rate is positive for about 60 percent of the tariff lines for which Chinese export taxes are (temporarily) lower than those allowed under its WTO commitments.

Generally, the VAT rebates are zero for 92 percent of the products on which the Chinese government levies an export tax. The fact that an export tax goes along with the highest possible VAT tax in most cases suggest that the Chinese government exploits export VAT rebates as an instrument before it resorts to export taxes.

3.8.3 Export tax as dependent variable

In this section we examine the determinants of the export tax. The export tax is modelled as a function of the pollution intensities, the resource dummies and the control variables as in Equation 3.2. In addition to the regressors used in the previous paragraph, we use the VAT tax as a control variable. Both the export tax and the VAT tax are likely to be determined by the same process, i.e. both variables are functions of a product's pollution intensities and political economy considerations. Hence, the VAT tax is correlated with the covariates in the regression of the export tax on the pollution intensities and the political economy variables. Omitting the VAT tax as a regressor would lead to an omitted variables bias unless the export tax is not related to the VAT tax.

As explained in Section 3.8.2, the Chinese government only implements export taxes that exceed the export tax allowed under the WTO accession protocol once it has exhausted the VAT tax as a policy instrument. This is similar to a situation in which the regulator chooses the VAT tax first and then chooses the export tax. This indicates that the causality runs from the VAT tax to the export tax but not the other way round. Our estimates are therefore unlikely to be biased due to reverse causality.

Table 3.7 displays the estimated relationships between the export tax, the pollution intensities and the control variables. Column 1 of Table 3.7 displays the results for a regression using data for the years 2005 to 2006. Columns 2 of the same table show the results for a sample covering the years 2007 to 2009.

There is evidence that the export tax is set in a way that discourages solid waste intensive exports. Table 3.7 shows a statistically significant positive relationship between the solid waste intensity and the export tax throughout the sample period. The relationship between the waste intensity and the export tax is significantly larger from 2007 on (see column 3 of Table 3.7) indicating that the introduction of export taxes could be geared towards a reduction in the generation of solid waste. However, even from 2007 on, the economic effect of a change in the solid waste intensity on the export tax is small. Table 3.8 displays the predicted change in the export tax as the pollution intensities increase from the 25th to the 75th percentile. Such an increase in the solid waste intensity is predicted to raise the export tax by 0.25 percentage points prior to 2007 and by 0.73 percentage points from 2007 on.

The results do not suggest, that the export tax is set with the objective

Table 3.7: Dependent variable: Export tax

	(1) 2005-2006	(2) 2007-2009	(3) Difference
Water Reg_gap*Int	−0.003**	−0.001	
	(0.001)	(0.001)	
COD Int	0.148	0.042	
	(0.107)	(0.227)	
Ammonium N. Int	4.721	−0.653	
	(3.768)	(11.903)	
Soot Reg_gap*Int	0.701	1.133	
	(0.839)	(3.083)	
SO2 Reg_gap*Int	0.223	−3.017***	***
	(0.288)	(1.014)	
Waste Int	0.002***	0.009***	***
	(0.001)	(0.001)	
Recycling Ratio	1.840**	3.708**	
	(0.890)	(1.564)	
Energy Int	−0.006*	−0.007	
	(0.003)	(0.004)	
Mineral	−0.452*	0.762	
	(0.265)	(0.469)	
Metal	0.953	1.138	
	(0.975)	(1.045)	
Wood	−1.124**	−1.119*	
	(0.539)	(0.631)	
Stones	−0.533	−1.097**	
	(0.358)	(0.449)	
Primary	0.615**	1.254***	***
	(0.302)	(0.442)	
L.Exp share [5-15)	−0.149	−0.139	
	(0.112)	(0.116)	
L.Exp share 15+	−0.107	0.296	
	(0.104)	(0.254)	
L.Employees	−0.050	0.250*	**
	(0.081)	(0.132)	
L.Firm No	0.034	−0.046	**
	(0.034)	(0.028)	
L.Profits	−0.001	0.002	
	(0.003)	(0.003)	
L.Δ Output	0.986***	2.630	
	(0.297)	(1.631)	
L.Labour Intensity	0.005	−0.009	
	(0.008)	(0.013)	
L.Export Intensity	−12.875***	−41.682*	
	(3.742)	(23.642)	
L.SOE share	0.153	−0.188	
	(0.618)	(0.896)	
L.Foreign share	0.302	−0.324	
	(0.442)	(0.915)	
L.Income tax	0.011	0.001	
	(0.011)	(0.009)	
VAT tax	0.126*	0.139***	
	(0.066)	(0.051)	
Tariff	−0.009	−0.023	
	(0.009)	(0.019)	
Observations	11373	16954	
r2	0.122	0.210	
F	200.405	1055.354	

Cluster robust standard errors in parentheses. Column 3 indicates whether there is a statistically significant difference in the coefficient estimates for the 2007-2009 sample compared to the 2005-2006 sample. No entry means that there is no statistically significant difference. * p<0.1, ** p<0.05, *** p<0.01

Table 3.8: Predicted change in the export tax

	(1) Before 2007	(2) From 2007 on
Water Reg_gap*Int	-0.436	-0.105
COD Int	0.056	0.010
Ammonium N. Int	0.142	-0.009
Soot Reg_gap*Int	0.070	0.037
SO2 Reg_gap*Int	0.042	-0.355
Waste Int	0.253	0.731
Recycling Ratio	0.260	0.481
Energy Int	-0.608	-0.565
Observations	11373	28327

Change from the 25th percentile to the 75th percentile

of reducing pollution along any other dimension. Most of the pollution intensities are not significantly related to the export tax. If anything, the export tax creates an incentive to produce SO_2 intensive products since the export tax is lower for those products from 2007 on.

Moreover, there is no evidence that the Chinese government uses export taxes to discourage exports of resources. There is no statistically significant positive relationship between the resource dummy variables and the export tax. To the contrary, the export tax is significantly lower for wood products and for precious stones from 2007 on.

However, the export tax is higher for primary products. Prior to 2007, primary products are taxed 0.6 percentage points more than processed products. Between 2007 and 2009, the export tax is 1.25 percentage points higher for primary products. This suggests that the Chinese government may have introduced export taxes for a range of products in an attempt to lure downstream producers to China where they have access to primary products at a lower price.

3.8.4 Determinants of VAT taxes

3.8.4.1 Estimation method

This section analyses the determinants of the VAT tax. In other words, we estimate Equation 3.2 with the VAT tax as dependent variable.[24]

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[24] The VAT tax can only take values between 0 and 17. Since the dependent variable can only take limited values, the data are censored. However, the percentage of observations with a VAT tax of 0 or 17 is less than 10 percent, respectively. Due to the small number of observations which take the limit value of 0 or 17, we chose to estimate the model using a pooled OLS regression. The results do not change

Since the export tax is correlated with the regressors in our model, we include it as a control variable in order to avoid an omitted variable bias. However, if the export tax is used as an independent variable, the causality might run from the export tax to the VAT tax. As argued in Section 3.8.2, the data show that the Chinese authorities set the maximum VAT tax before they introduce export taxes that might violate China's obligations under the WTO accession protocol. This suggest that the VAT tax affects the choice of the export tax. If that is the case, we need to instrument for the export tax in order to avoid biased estimates due to reverse causality.

We use the maximum export tax allowed under China's WTO Accession Protocol as an instrument for the export tax. The maximum export tax which is allowed under the WTO Accession Protocol is arguably exogenous to the export tax in the mid 2000s, since the Accession Protocol was negotiated at the end of the 1990s and became effective in 2001.

The export taxes that are actually implemented in China differ from the export taxes negotiated under the WTO Accession Protocol. The Chinese government is free to set export taxes that are lower than those allowed under the Accession Protocol and chose to do so in several instances. Moreover, the government introduced temporary export taxes for products for which the WTO Accession Protocol does not foresee any export taxes. However, the actual export tax is positively correlated with the export tax allowed under the accession protocol. The correlation coefficient between the two variables is 0.47.

3.8.4.2 Results

Prior to the discussion of our results, we assess the quality of our instrument and the necessity of an instrumental variable procedure. The F-statistic for the first-stage regression shows that the instruments are jointly highly significant and that the 2SLS results do not suffer from problems related to weak instruments. We also test for the exogeneity of the export tax using a test that allows for clustered standard errors and reject the null-hypothesis that the export tax is exogenous.[25]

The results for the regression with the VAT tax as dependent variable are displayed in Table 3.9. The relationship between the VAT tax and the pollution intensities shows a similar pattern as the relationship between the overall export tax and the pollution intensities.

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significantly if we use a Tobit model which takes account of censoring.

[25] We use the user-written ivreg2 command (Baum et al., 2002).

Table 3.9: Dependent variable: VAT tax

	(1) 2005-2006	(2) 2007-2009	(3) Difference
Water Reg_gap*Int	0.003**	0.012*	
	(0.002)	(0.004)	
COD Int	1.525***	−1.418	**
	(0.353)	(1.093)	
Ammonium N. Int	−7.090*	42.871*	**
	(3.859)	(25.302)	
Soot Reg_gap*Int	−3.005**	−4.591	
	(1.412)	(6.338)	
SO2 Reg_gap*Int	0.563	4.209*	
	(0.697)	(2.313)	
Waste Int	0.001	−0.006**	***
	(0.001)	(0.003)	
Recycling Ratio	1.190	6.471	
	(1.847)	(5.358)	
Energy Int	0.008***	0.036***	***
	(0.003)	(0.008)	
Mineral	2.511***	5.735***	***
	(0.457)	(0.830)	
Metal	0.657	4.481***	***
	(0.451)	(1.450)	
Wood	6.634***	6.560***	
	(0.734)	(0.778)	
Stones	2.712*	4.073***	
	(1.550)	(0.820)	
Primary	1.131*	0.617	
	(0.651)	(0.898)	
L.Exp share [5-15)	0.094	−0.197	*
	(0.187)	(0.183)	
L.Exp share 15+	0.204	−0.143	
	(0.342)	(0.371)	
L.Employees	0.015	−0.808***	***
	(0.196)	(0.282)	
L.Firm No	−0.126**	−0.047	
	(0.053)	(0.055)	
L.Profits	0.006	0.002	
	(0.004)	(0.005)	
L.Δ Output	0.811	3.487	
	(0.497)	(3.261)	
L.Labour Intensity	0.003	0.048	
	(0.019)	(0.060)	
L.Export Intensity	19.721	43.181	
	(20.779)	(44.559)	
L.SOE share	−5.455***	−9.189***	
	(1.407)	(3.402)	
L.Foreign share	−1.990*	−0.519	
	(1.103)	(2.606)	
L.Income tax	0.057**	0.092**	
	(0.024)	(0.039)	
Tariff	−0.023**	−0.031	
	(0.009)	(0.022)	
Export tax	0.489***	0.328***	
	(0.187)	(0.102)	
Observations	11373	16954	
r2	0.451	0.614	
F	1292.568	273.398	

Cluster robust standard errors in parentheses. Column 3 indicates whether there is a statistically significant difference in the coefficient estimates for the 2007-2009 sample compared to the 2005-2006 sample. No entry means that there is no statistically significant difference. * p<0.1, ** p<0.05, *** p<0.01

The data support the NDRC's claim that the VAT rebates aim at reducing energy consumption. The VAT tax is found to be significantly higher for energy-intensive products, thus discouraging exports of those products. The effect of an increase in energy intensity is significantly larger from 2007 on suggesting that the VAT rebate rate adjustments could aim at reducing the energy use of Chines exports. The difference between the coefficient estimates for energy intensity for the 2005-06 and the 2007-09 samples is economically meaningful. Table 3.10 shows that the VAT tax is predicted to be 2.8 percentage points higher for a product with a pollution intensity at the 75th percentile than for a product with a pollution intensity at the 25th percentile, ceteris paribus. Prior to 2007, a similar change in the energy intensity is associated with a change in the VAT tax of no more than 0.75 percentage points.

The VAT tax is also significantly positively related to the waste water intensity (interacted with the regulatory gap). This indicates that the VAT taxes discourage exports of waste water intensive products particularly from 2007 on. Table 3.10 demonstrates that a surge in the waste water intensity from the 25th to the 75th percentile is associated with an increase in the VAT tax by about 0.93 percentage points for the period 2007 to 2009.

Table 3.10: Predicted change in the VAT tax

	(1) Before 2007	(2) From 2007 on
Water Reg_gap*Int	0.572	0.928
COD Int	0.580	−0.353
Ammonium N. Int	−0.213	0.590
Soot Reg_gap*Int	−0.299	−0.151
SO2 Reg_gap*Int	0.106	0.496
Waste Int	0.063	−0.545
Recycling Ratio	0.168	0.839
Energy Int	0.749	2.816
Observations	11373	16954

Change from the 25th percentile to the 75th percentile

Moreover, the VAT rebate adjustments could lead to a reduction of ammonium nitrogen emissions. Before 2007, the structure of VAT taxes encourages exports of ammonium nitrogen intensive products, as represented by the statistically significant negative coefficient estimate for the ammonium nitrogen intensity in the first column of Table 3.9. This changed once the VAT rebate rates were adjusted. From 2007 on, there is a statistically significant positive relationship between the VAT tax and the ammonium nitrogen intensity. Moreover, the VAT tax is significantly higher for SO_2 intensive exports in the 2007 to 2009 sample. If an increase in the VAT tax reduces exports, the VAT rebate adjustments could lead to reductions in SO_2 and ammonium nitrogen emissions.

The results suggest that the VAT tax is not driven by concerns about the generation of solid waste and recycling. The coefficient estimate for the solid waste intensity is statistically significant and negative from 2007 on. The recycling ratio is not significantly related to the VAT tax. Furthermore, the Chinese government does not seem to adjust the VAT rebate rates with the objective of reducing COD emissions. The VAT tax is set in a way that discourages exports of COD discharge intensive products prior to the reform. However, from 2007 on, there is no statistically significant relationship between the COD intensity and the VAT tax.

The results in Table 3.9 also demonstrate that the VAT taxes hamper exports of natural resources. The coefficient estimates for the resource dummies are large and statistically significant, particularly for the period from 2007 on. In the 2007 to 2009 sample, the VAT tax for mineral products is estimated to be 5.7 percentage points higher than the VAT tax for non-mineral products. The difference in the average VAT tax between wood exports and other products is even larger and amounts to 6.6 percentage points. On average, exporters of stone and metal products face a VAT tax that is 4.1 and 4.5 percentage points larger than the VAT tax for non-resource products, respectively. This gives strong support to the idea that VAT taxes aim at protecting China's natural resources.

Based on the coefficient estimates for the variable *Primary*, we cannot conclude that the VAT rebates were adjusted in an attempt to attract downstream producers to China. The VAT tax is significantly larger for primary products before 2007 but not from 2007 on.

The sign of the coefficient estimates for the control variables is in line with our expectations. We find that the VAT tax is significantly lower in industries with a larger number of employees from 2007 on. This is in line with Caves (1976)'s argument that larger industries receive more protection. In addition, the results indicate that industries with a larger output share of state-owned enterprises face a lower VAT tax.

The VAT tax is also higher for products with a higher export tax. An increase in the export tax by one percentage point is associated with an increase in the VAT tax by 0.49 percentage points before 2007 and by

0.33 percentage points from 2007 onwards. Moreover, protection on the import side seems to be complementary to the VAT tax. A reduction in the tariff increases competition between domestic producers and world market producers. In a similar way, an increase in the VAT tax generates a disadvantage for domestic producers compared to producers in the world markets. The finding that the VAT tax is higher for products with a lower tariff, thus, indicates that tariffs and VAT taxes are complementary. However, the coefficient estimate is not statistically significant in the 2007-2009 sample.

3.8.5 Protection on the import side

The Chinese government cannot only use export taxes and VAT taxes as second-best policy instrument to reduce pollution. The first chapter of this thesis showed that it is also possible to use import tariffs as second-best environmental policy. Based on the results presented in Chapter 1, a government which uses tariffs as a second-best environmental policy, sets lower tariff rates for goods which are more pollution intensive. This encourages imports of polluting products from abroad. If clean industries are protected by high tariffs, more resources are allocated to the production of clean goods and the pollution emissions in the economy declines.

To the best of our knowledge, the Chinese government did not claim to adjust import tariffs for environmental reasons. Statements which link trade policy to environmental objectives only refer to export restrictions such as export taxes and export VAT rebates. Hence, it would not be surprising if import tariffs were not related to the pollution intensities or the resource dummy variables. Yet, it is worth exploring the correlation between the import tariffs and the pollution intensities in order to see whether import tariffs are motivated by similar concerns as export taxes and export VAT rebates.

In order to investigate whether the tariff rates reflect environmental concerns, we regress the applied MFN advalorem tariff on the pollution intensities, the resource dummies and a set of control variables. In other words, we estimate the model which was presented in Equation 3.2 in Section 3.5. However, the dependent variable is now the ad valorem tariff.[26]

If the tariffs are set in an attempt to reduce pollution, the coefficient

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[26] The results on the determinant of import tariffs should be taken with a grain of salt since we only analyse the applied MFN tariff. However, China grants preferential access for certain products from a number of trading partners. The analysis in this chapter does take account of lower tariff rates due to preferential access.

estimates for the pollution intensities should have a negative sign. The only exception is the recycling ratio. Tariffs are higher for goods with a high recycling ratio if the government aims at protecting industries which recycle a large proportion of the solid waste.

The set of control variables differs slightly from the control variables we used in the regression with the VAT tax or the export tax as dependent variables. We have to make a few adjustments to the regressors in the model in order to reflect the fact that we are looking at the import side. For one thing, we use the import intensity, defined as imports relative to industry output, instead of the export intensity used in previous sections. For another thing, we do not use the share of global exports as a measure for the terms of trade motive, but the share of Chinese imports relative to global imports. We use three categories which capture China's role as an importer on the world market. The base category is an import share of less than 5 percent and captures the case in which China does not have market power. The dummy variable "Imp share [5-15)" takes the value of 1 if China imports between 5 and 15 percent of global imports. If China imports more than 15 percent of global trade, the dummy variable "Imp share 15+" takes the value of 1. The coefficient estimates for the dummy variables should be positive if the import tariffs are set in an attempt to manipulate the terms of trade.

The results for a regression with the ad valorem tariff as dependent variable are presented in Table 3.11. Column 1 of Table 3.11 shows the results for a regression using observations for the years 2005 to 2006. Column 2 displays the coefficient estimates for the 2007 to 2009 sample.

There is evidence that import tariffs are 7 percent lower for wood products in the 2005 to 2006 sample and 9 percent lower in the 2007 to 2009 sample. This tariff structure fosters imports of wood products and it is complementary to the structure of the VAT tax. The latter is significantly higher for wood products and, thus, discourages exports of wood products. The tariffs rates and the VAT rebate rates, thus, jointly support the protection of China's forests.

The results also reveal a negative relationship between the COD intensity and the ad valorem tariff. An increase in the COD intensity from the 25th to the 75th percentile is associated with a predicted reduction in the tariff by 1 percentage point in the 2005 to 2006 sample and by 0.8 percent points in the 2007 to 2009 sample (see Table 3.12). The low tariff rates for COD intensive products foster imports of those products and can, thus, lead to a

Table 3.11: Dependent variable: Import tariff

	(1) 2005-2006	(2) 2007-2009	(3) Difference
Water Reg_gap*Int	0.010*	0.004	
	(0.006)	(0.007)	
COD Int	−2.690**	−3.103*	
	(1.020)	(1.673)	
Ammonium N. Int	1.080	27.143	
	(12.184)	(19.928)	
Soot Reg_gap*Int	4.271*	3.983	
	(2.226)	(8.250)	
SO2 Reg_gap*Int	−0.142	1.403	
	(1.703)	(1.779)	
Waste Int	0.000	0.001	
	(0.002)	(0.002)	
Recycling Ratio	6.324	11.455**	
	(5.522)	(5.269)	
Energy Int	−0.016	−0.011	
	(0.009)	(0.012)	
Mineral	−3.164*	−2.378	*
	(1.844)	(1.636)	
Metal	1.502	1.495	
	(0.963)	(0.994)	
Wood	−7.429***	−9.125***	***
	(1.509)	(1.428)	
Stones	1.673	2.239	
	(4.509)	(4.802)	
Primary	−1.284	−1.227	
	(1.421)	(1.468)	
L.Imp share [5-15)	−2.079***	−2.092***	
	(0.514)	(0.503)	
L.Imp share 15+	−1.774**	−2.201***	
	(0.739)	(0.699)	
L.Employees	−0.909*	−0.882**	
	(0.478)	(0.342)	
L.Firm No	0.153	0.068	
	(0.140)	(0.088)	
L.Profits	0.021	0.003	
	(0.015)	(0.006)	
L.Δ Output	−2.405**	1.670	
	(1.139)	(2.846)	
L.Labour Intensity	0.112**	0.143**	
	(0.053)	(0.059)	
L.Import Intensity	−18.113	−62.112***	***
	(10.787)	(22.123)	
L.SOE share	−16.194***	−19.713***	
	(3.327)	(3.587)	
L.Foreign share	−0.884	−1.591	
	(3.239)	(3.547)	
L.Income tax	0.409***	0.288***	***
	(0.054)	(0.034)	
Overall export tax	−0.141***	−0.111***	
	(0.046)	(0.040)	
Observations	11373	16954	
r2	0.243	0.250	
F	150.145	116.288	

Cluster robust standard errors in parentheses. Column 3 indicates whether there is a statistically significant difference in the coefficient estimates for the 2007-2009 sample compared to the 2005-2006 sample. No entry means that there is no statistically significant difference. * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Table 3.12: Predicted change in the import tariff

	(1) Before 2007	(2) From 2007 on
Water Reg_gap*Int	1.623	0.325
COD Int	-1.023	-0.773
Ammonium N. Int	0.033	0.373
Soot Reg_gap*Int	0.425	0.131
SO2 Reg_gap*Int	-0.027	0.165
Waste Int	0.053	0.090
Recycling Ratio	0.893	1.485
Energy Int	-1.569	-0.873
Observations	11452	28327

Change from the 25th percentile to the 75th percentile

a contraction of COD intensive industries. Moreover, the recycling ratio is significantly positively correlated with the import tariff in the 2007 to 2009 sample. This positive coefficient estimate is in line with the actions of a regulator who aims at reducing the solid waste intensity of production in China.

However, the results do not indicate that the Chinese government adjusts the tariff rates in order to reduce pollution from 2007 on. The last column of Table 3.11 shows that there is no statistically significant difference in the coefficient estimates for any of the pollution intensities in the 2007 to 2009 sample compared to the 2005 to 2006 sample. This supports the notion that import tariffs were not adjusted with the intention of changing the pollution outcome.

China's import tariffs do not seem to be driven by an attempt to manipulate the terms of trade in China'a favour either. Tariffs are significantly lower for products for which China imports a large proportion of global imports. A country which tries to manipulate the terms of trade would set higher tariffs for products for which it is a large importer.

Since Chinese officials only link changes in export restrictions to environmental motives and since there is little evidence of tariff adjustments which were motivated by environmental concerns, the sensitivity analysis in this chapter focuses on the export taxes and export VAT rebates.

3.8.6 Difference between the determinants of VAT taxes, export taxes and tariffs

The results suggest that the VAT tax, the export tax and the tariffs are driven by different factors, in particular with respect to the resource dummy variables and the environmental variables. The Chinese government uses VAT rebate rates to discourage exports of natural resources, waste water and energy intensive products. Moreover, the VAT rebate reforms from 2007 onwards could hamper exports of ammonium nitrogen and SO_2 intensive products, since the VAT tax is considerably higher for those products from 2007 on. The export tax, on the other hand, discourages exports of solid waste intensive products and primary products. Tariffs are set in a way that encourages imports of COD intensive products, products with a low recycling ratio as well as wood products.

Out of the three trade policy instruments, the VAT tax varies most during the sample period and an attempt to reduce pollution and conserve natural resources is most obvious in the structure of the VAT tax. This is not surprising since the VAT tax is the only trade policy instrument which China is allowed to choose to its liking. The choice of export taxes and import tariffs is constrained due to China's obligations as a member of the WTO. China cannot set tariffs which exceed the WTO bound tariffs and according to (WTO, 2008, Section III), China's applied tariffs follow the bound tariffs closely.

3.9 Sensitivity analysis

This section analyses the sensitivity of our results. Since China's WTO Accession protocol constrains the use of export taxes and the Chinese government only levies export taxes on less than 300 out of more than 5700 products in our sample, most of the variation in trade policy results from variation in the VAT rebate rates. The sensitivity analysis therefore focuses on regressions with the VAT rebate rate as dependent variable. Regression results for the same sample period with the export tax as dependent variable can be found in Tables 3.22 and 3.23 in the Appendix. Moreover, the sensitivity analysis focuses on the time period from 2007 onwards, since the Chinese authorities link trade policy to environmental concerns during this time period.

3.9.1 Only manufacturing industries

Our sample contains a broad spectrum of industries. In this section, we restrict the sample to manufacturing industries and exclude extractive industries like *Mining and Washing of Coal*, *Extraction of Petroleum and Natural Gas* and Mining and Processing of Metal and Non-Metal Ores. Moreover, the sectors *Recycling and Disposal of Solid Waste* and *Production and Supply of Energy* are removed from the sample. All of the extractive industries as well as power generation and supply are classified as resource intensive and Table 3.21 in the Appendix shows that they are amongst the most polluting industries. Therefore, we investigate whether the positive correlation between the VAT tax and the pollution intensities follows through in a sample without the above-mentioned resource- and pollution-intensive industries.

The regression results are presented in Column 1 of Table 3.13. The results are very similar to those we obtained for the entire sample. The VAT tax is significantly higher for minerals, wood products and precious stones as well as waste water, ammonium nitrogen, SO_2 and energy intensive products. The magnitude of the coefficient estimates is similar to the magnitude of the coefficient estimates in the baseline regression.

3.9.2 No market power

The theoretical model shows that the second-best export tax is also driven by an incentive to manipulate the world market price of exports. This terms of trade motive is difficult to measure. In the main analysis we proxy the terms of trade motive using dummy variables for the lag of China's share in global exports. However, we want to scrutinize the terms of trade motive further.

As a robustness check, we only look at observations for which China is a small producer in the world market. There is no incentive to set an export tax or a VAT tax in order to manipulate the terms of trade if the industry is small on the world market. Hence, we look at a sample of products for which China exports less than 15 percent of global exports. The results are presented in Column 2 of Table 3.13. They are similar to the results for the unrestricted sample.

Table 3.13: Sensitivity analysis: Dependent variable VAT tax

	(1) Manufacturing	(2) Small	(3) 2007	(4) No controls
Water Reg_gap*Int	0.014***	0.009**	0.009**	0.012**
	(0.005)	(0.005)	(0.004)	(0.005)
Water Int				
COD Int	−1.841	−0.483	−0.311	−0.302
	(1.130)	(1.180)	(1.089)	(1.396)
Ammonium N. Int	47.438**	53.242*	5.020	−27.027
	(22.014)	(27.713)	(19.319)	(22.064)
Soot Reg_gap*Int	−4.002	−5.654	−10.528	−4.558
	(5.297)	(6.809)	(6.433)	(14.537)
Soot Int				
SO2 Reg_gap*Int	7.331***	4.696*	4.916**	6.748
	(2.608)	(2.638)	(2.323)	(4.453)
SO2 Int				
Waste Int	0.003	−0.007**	−0.008*	−0.003
	(0.017)	(0.004)	(0.004)	(0.004)
Recycling Ratio	2.968	7.686	8.604	8.170
	(7.952)	(7.279)	(5.625)	(9.272)
Energy Int	0.038***	0.035***	0.031***	0.035***
	(0.013)	(0.008)	(0.007)	(0.007)
Mineral	5.565***	5.329***	4.186***	
	(0.818)	(0.733)	(0.683)	
Wood	7.523***	6.448***	4.913***	
	(1.111)	(0.921)	(0.712)	
Stones	2.040*	4.082***	2.167*	
	(1.140)	(0.709)	(1.115)	
Metal	2.720	4.571***	3.690***	
	(1.720)	(1.556)	(1.318)	
Primary	0.595	0.558	1.232	
	(0.732)	(0.927)	(0.812)	
L.Exp share [5-15)	−0.170		0.278	
	(0.193)		(0.172)	
L.Exp share 15+	−0.103		0.252	
	(0.371)		(0.280)	
L.Employees	−0.684**	−0.939***	−0.330	
	(0.287)	(0.358)	(0.267)	
L.Firm No	−0.056	−0.051	−0.188***	
	(0.064)	(0.065)	(0.062)	
L.Profits	−0.003	0.005	0.016**	
	(0.006)	(0.006)	(0.007)	
L.Δ Output	−0.496	2.369	6.668*	
	(3.323)	(3.395)	(3.448)	
L.Labour Intensity	0.075	0.161*	0.060	
	(0.056)	(0.090)	(0.044)	
L.Export Intensity	−11.054	127.290***	60.581*	
	(44.969)	(46.096)	(33.979)	
L.SOE share	−10.559***	−8.569**	−9.976***	
	(3.017)	(3.783)	(2.205)	
L.Foreign share	0.553	−3.569	−5.259***	
	(3.359)	(3.217)	(1.782)	
L.Income tax	0.098***	0.090**	0.098***	
	(0.030)	(0.038)	(0.031)	
Export tax	0.441***	0.361***	0.256**	0.578***
	(0.126)	(0.122)	(0.107)	(0.162)
Tariff	−0.043	−0.031	−0.046**	
	(0.027)	(0.022)	(0.018)	
Observations	14990	10787	5700	17147

Cluster robust standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

3.9.3 Effects of the economic and financial crisis

The sample period includes the years of the economic and financial crisis which had a large negative impact on Chinese exports in some product categories. When Chinese exports plummeted, the Chinese government reversed some of the earlier reductions in VAT rebates to support its export industries. From the end of 2008 on, there were several VAT rebate reforms in which the Chinese government increased the VAT rebate rates for particular industries.[27] The summary statistics in Table 3.4 show that, as a consequence, the average VAT tax declined in 2009.

In order to demonstrate that our results are not driven by VAT rebate adjustments in response to the economic and financial crisis, we restrict the sample to the year 2007 instead of using observations for the years 2007-2009. The results presented in Column 4 of Table 3.13 corroborate our findings from the previous sections of this chapter. The VAT tax is significantly positively correlated with the waste water intensity, the SO_2 intensity and the energy intensity. The coefficient estimates are of a similar magnitude as in the baseline regression, indicating that the VAT tax may aim at reducing pollution along those dimensions.

Table 3.24 in the Appendix provides more insights into the development of the relationship between the VAT rebate rates and the pollution intensities over time. We split the sample into five years and regress the VAT tax on the pollution intensities and the control variables for each year in the sample separately. The first column of Table 3.24 shows the results of a regression which uses observations for the year 2005, the last column uses observations for the year 2009. Table 3.24 reveals stark changes in the relationship between the VAT tax and the waste water intensity as well as the energy intensity in 2007. In the aftermath of the economic and financial crisis, some of these changes were reversed. However, the strong positive correlation between the VAT rebate rates and the resource dummy variables pertains even after the crisis.

The results for equivalent regressions with the export tax and the ad valorem tariff as dependent variables are shown in Table 3.25 and 3.26 in the Appendix. The results in the latter two tables confirm the patterns found in Sections 3.8.3 and 3.8.5. However, the adjustments in export taxes and import tariffs are not reversed after the crisis.

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[27] See Table 3.18 in the Appendix for details on the dates of the reforms.

3.9.4 No control variables

Our analysis investigates the relationship between the VAT tax and the pollution intensities, controlling for a host of other motives to manipulate VAT rebate rates. However, there is a concern that the pollution intensities are correlated with the control variables and that the results are affected by multicollinearity. Therefore, Column 5 of Table 3.13 shows the results of a regression in which the pollution intensities are the only regressors and all control variables are omitted. The results confirm a statistically significant and positive correlation between the VAT tax and the waste water as well as the energy intensity. The SO_2 intensity is also positively correlated with the VAT tax. However, the standard errors are larger than in the baseline regression and the coefficient estimate is not statistically significant.

3.9.5 No measure for the regulatory gap

In our baseline regression, we interact the waste water intensity, the soot intensity and the SO_2 intensity with the share of emissions meeting discharge standards. The latter variable captures the regulatory gap which proxies the difference between marginal damage and the pollution tax in the theoretical model.

In order to investigate whether this measure for the regulatory gap drives our results, we include the waste water, soot and SO_2 intensities as regressors without interacting them with the measure for the regulatory gap. As mentioned above, the relevant Five Year Plans foresee reductions in SO_2 and soot emissions as well as water consumption, indicating that the pollution tax is lower than marginal damage. Moreover, the share of emissions exceeding discharge standards is positive for all industries and all years in the sample. With the pollution tax not internalizing the environmental distortion to the desired extent, we would expect a positive relationship between soot, SO_2 and waste water intensities and the VAT tax.

The regression results for a model which does not interact the pollution intensities with a measure for the regulatory gap are displayed in Column 1 of Table 3.14. As in the baseline regression, the VAT tax is significantly higher for SO_2 insensitive products and not significantly related to the soot intensity. The coefficient estimate for the waste water intensity, however, is not statistically significant, indicating that the positive relationship between the waste water intensity and the VAT tax only holds if we consider

Table 3.14: Sensitivity analysis: Dependent variable VAT tax

	(1) No Reg_gap	(2) Direct	(3) Fixed pollution
Water Reg_gap*Int		0.004	0.004
		(0.013)	(0.004)
Water Int	−0.001		
	(0.001)		
COD Int	4.886	1.944	0.567
	(2.996)	(3.186)	(0.735)
Ammonium N. Int	76.304**	11.706	−4.374
	(37.108)	(28.188)	(12.531)
Soot Reg_gap*Int		−24.596	−5.236
		(16.477)	(3.377)
Soot Int	−8.958		
	(6.584)		
SO2 Reg_gap*Int		10.016	1.032
		(6.742)	(1.537)
SO2 Int	5.561*		
	(2.945)		
Waste Int	−0.002	−0.010*	−0.001
	(0.002)	(0.005)	(0.002)
Recycling Ratio	12.775**	0.693	16.145*
	(5.598)	(3.331)	(8.539)
Energy Int	0.024**	0.052***	0.026***
	(0.010)	(0.013)	(0.008)
Mineral	5.970***	4.368***	4.525***
	(0.812)	(0.659)	(0.742)
Wood	6.692***	6.156***	5.231***
	(0.802)	(0.617)	(0.814)
Stones	3.951***	1.416	1.989*
	(0.862)	(1.065)	(1.167)
Metal	4.381***	2.979***	3.794***
	(1.445)	(1.123)	(1.381)
Primary	1.356	1.196*	1.291*
	(0.975)	(0.624)	(0.778)
L.Exp share [5-15)	−0.224	0.238	0.292
	(0.182)	(0.164)	(0.179)
L.Exp share 15+	−0.197	0.192	0.216
	(0.370)	(0.309)	(0.330)
L.Employees	−0.488	−0.344	−0.005
	(0.392)	(0.345)	(0.263)
L.Firm No	−0.074	−0.104*	−0.174***
	(0.056)	(0.054)	(0.058)
L.Profits	−0.000	0.001	0.005
	(0.007)	(0.010)	(0.010)
L.Δ Output	4.756	2.912	7.314
	(3.634)	(3.941)	(5.660)
L.Labour Intensity	0.056	0.056	0.060
	(0.067)	(0.050)	(0.062)
L.Export Intensity	57.141	52.558*	71.078**
	(43.726)	(31.487)	(34.084)
L.SOE share	−12.719***	−13.797***	−8.859***
	(3.530)	(2.665)	(2.649)
L.Foreign share	−1.512	−4.297**	−4.308**
	(2.323)	(1.813)	(1.912)
L.Income tax	0.117***	0.134***	0.092**
	(0.039)	(0.031)	(0.038)
Export tax	0.267***	0.245***	0.256**
	(0.098)	(0.095)	(0.105)
Tariff	−0.031	−0.051***	−0.055***
	(0.021)	(0.018)	(0.018)
Observations	17022	5700	5700

Cluster robust standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

differences in the industrys' compliance with discharge standards.

This result should not be interpreted as evidence that the structure of Chinese VAT rebates rates is not set in a way that could reduce waste water emissions. It rather highlights the importance of using economic theory to guide the empirical analysis. Based on the theory, the correct specification requires an interaction term between the pollution intensity and the regulatory gap. Omitting the regulatory gap can be considered a misspecification and the misspecified model would suggest that the Chinese government does not have reductions in waste water emissions in mind when it sets the VAT rebate rates.

3.9.6 Pollution intensities fixed

When governments introduce pollution taxes per unit of emission, firms have an incentive to invest in pollution abatement and cleaner production techniques. The pollution tax may, thus, lead to a reduction in the pollution intensity. Export taxes, on the other hand, are charged per unit of exports, irrespective of the pollution intensity of production. Therefore, export taxes do not incentivize firms to invest in cleaner production techniques and we do not worry about reverse causality between the export tax and the pollution intensity in the baseline model. Moreover, the summary statistics in Section 3.7 indicate the pollution intensities decline gradually over the course of the sample period. The do not change drastically after the change in export taxes and VAT rebate rates in 2007, corroborating the absence of reverse causality.

Reverse causality is only a concern if the pollution intensity depends on the production quantity and if the export tax affects the production quantity. For example, there could be a scale effect in pollution abatement, implying that an increase in production would be associated with a lower pollution intensity. On the other hand, a firm may have new and clean machines as well as old machines. When the output is low, the firm uses clean machines. As soon as the output increases, the firm additionally uses the old an pollution intensive production processes. In that case, an increase in production would lead to a higher pollution intensity.

In order to address this concern, we fix the pollution intensities at the 2005 level and regress the VAT tax for the years 2007 to 2009 on the pollution intensities for the year 2005. This guarantees that the pollution intensities are not affected by the changes in export taxes and export VAT rebates from 2007 on. The remainder of the regressors is not kept fixed and changes over the sample period.

The regression results are presented in Column 2 of Table 3.14. They confirm the finding that the VAT tax increases in a product's energy intensity and in ratio of solid waste which is utilized. Only the former finding suggests an environmental motivation for the VAT tax. Once we eliminate the time variation in the pollution intensities, the VAT tax is not significantly related the any of the other pollution intensities.

However, this does not necessarily contradict our previous findings. Keeping pollution intensities fixed at the 2005 level yields false results if the ranking of industries in terms of their pollution intensities changes over the course of the sample period. The use of the VAT tax as a second-best environmental policy instrument requires a positive correlation between the export tax and the VAT tax in the cross-section. The VAT tax should be highest for the most polluting product. Let us denote this product by p for now. If production techniques for product p become cleaner over the course of the sample period, the VAT tax should no longer be largest for product p at the end of the sample period. If we keep pollution intensities fixed at the 2005 level, we cannot capture this.

3.9.7 Direct pollution intensities

Our empirical analysis investigates the relationship between trade policy instruments and the overall pollution intensities. However, the calculation of overall pollution intensities is based on certain assumptions. Firstly, we have to assume that the input-output coefficients are constant over time, since IO tables are only published every five years and there is only one IO table for our sample period. Secondly, Chinese IO tables do not provide any information about imported intermediate inputs. Therefore, we have to make proportionality assumptions.

Due to these shortcomings of Chinese IO tables, other authors suggest using direct emission intensities rather than overall emission intensities (see e.g. Dean and Lovely, 2010). The use of direct pollution intensities is not necessarily an improvement compared to the use of overall pollution intensities. Direct pollution intensities also assume constant input-output coefficients. The elements of the Leontief inverse are 1 for inputs from industry i to in industry i and 0 for inputs from industry i to industry j. This is not the case in the real world. Since those input-output coefficients are not correct, the analysis should be based on overall pollution intensities. For the sake of completeness, we still estimate the baseline model using direct pollution intensities rather than overall pollution intensities.

The estimated relationship between the direct pollution intensities and the VAT tax for the years 2007 to 2009 are shown in Column 3 of Table 3.14. As in the baseline regression, the VAT tax is significantly higher for energy intensive products. Hence, there is strong support for the notion that the VAT rebates are set in a way that hamper exports of energy intensive products. However, there is no statistically significant positive relationship between the VAT tax and any of the other pollution intensities in the 2007-2009 sample. This indicates that the use of direct emissions intensities may lead to different conclusions. When we use overall pollution intensities and take the pollution in the entire production process into consideration, we find that the VAT tax also discourages exports of waste water and ammonium nitrogen intensive exports.

3.10 Conclusion

From 2007 on, the Chinese government repeatedly emphasised that it uses export taxes as well as VAT rebates as second-best environmental policy instruments. This chapter investigates whether, in practice, concerns about pollution drive Chinese trade policy reforms.

Environmental issues are of increasing importance on the Chinese policy agenda. However, the design of the Chinese pollution levy system and the decentralized implementation and enforcement of pollution regulation pose a challenge to internalizing the environmental distortion. Given this constraint on the use of domestic pollution taxes, export taxes can be used as a second-best policy instrument to protect the environment.

Based on an extension of Copeland (1994)'s model to the large country case, it is possible to show that the second best export tax increases in a product's pollution intensity. This relationship guides our empirical analysis. This chapter investigates whether the export tax and the difference between the VAT and the VAT rebate are positively correlated with a product's air, water, solid waste and energy intensity. The analysis is based on product-level trade policy data as well as data on Chinese pollution emissions and energy use spanning the years 2005 to 2009.

The results presented in this chapter lend support to the Chinese authorities' claim that the export VAT rebate adjustments are driven by environmental concerns. This chapter shows that VAT rebate rates are set in a way which discourages exports of water pollution intensive and energy intensive and products. Moreover, the conservation of natural resources such as minerals, metals, wood products and precious stones seems to be a key determinant of China's VAT rebate rates.

However, there is little evidence that the export tax is used as a secondary instrument to reduce pollution or conserve natural resources. The export tax seems to be motivated by an attempt to protect downstream producers in China, since the export taxes are higher for primary products.

3.11 Appendix to Chapter 3

Table 3.15: Emission reduction targets

Pollutant	10th FYP (2001-2005)	11th FYP (2006 - 2010)
Water consumption	-	Reduction in water consumption per unit of industrial value by 30%
COD	10% reduction	10% reduction
Ammonium nitrogen	10% reduction	-
SO_2	10% reduction	10% reduction
Soot	9% reduction	-
Dust	17% reduction	-
Generation of solid waste	10% reduction	-
Recycling	Recycle 50% of solid waste by 2005	Recycle 60% of solid waste by 2010
Energy	-	Reduce energy consumption per unit of GDP by 20%

Emission reduction targets are defined as a reduction in emissions at the end of the FYP period compared to emissions at the beginning of the FYP period unless otherwise specified.

Table 3.16: List of sectors

Sectors in the dataset
Mining and Washing of Coal
Extraction of Petroleum and Natural Gas
Mining and Processing of Ferrous Metal Ores
Mining and Processing of Non-Ferrous Metal Ores
Mining and Processing of Nonmetal Ores and Other Ores
Processing of Food from Agricultural Products
Manufacture of Foods
Manufacture of Beverages
Manufacture of Tobacco
Manufacture of Textile
Manufacture of Textile Wearing Apparel, Footware, and Caps
Manufacture of Leather, Fur, Feather and Related Products
Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products
Manufacture of Furniture
Manufacture of Paper and Paper Products
Printing, Reproduction of Recording Media
Manufacture of Articles For Culture, Education and Sport Activity
Processing of Petroleum, Coking, Processing of Nuclear Fuel
Manufacture of Raw Chemical Materials and Chemical Products
Manufacture of Medicines
Manufacture of Chemical Fibers
Manufacture of Rubber
Manufacture of Plastics
Manufacture of Non-metallic Mineral Products
Smelting and Pressing of Ferrous Metals
Smelting and Pressing of Non-ferrous Metals
Manufacture of Metal Products
Manufacture of General Purpose Machinery
Manufacture of Special Purpose Machinery
Manufacture of Transport Equipment
Manufacture of Electrical Machinery and Equipment
Manufacture of Communication Equipment, Computers and Other Electronic Equipment
Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work
Manufacture of Artwork and Other Manufacturing
Recycling and Disposal of Waste
Production and Distribution of Electric Power and Heat Power

Table 3.17: Data source

Variables	**Data Source**
VAT tax	China Customs, State Administration of Taxation, Ministry of Finance (see Table 3.18 for details)
Export tax	China Customs Homepage
Tariff	WITS TRAINS database
Waste Water Vol	China Statistical Yearbook on Environment
COD Vol	China Statistical Yearbook on Environment
Waste Gas	China Statistical Yearbook on Environment
Soot Emission	China Statistical Yearbook on Environment
Soot Stand_Rat	China Statistical Yearbook on Environment
SO_2 Emission	China Statistical Yearbook on Environment
SO_2 Stand_Rat	China Statistical Yearbook on Environment
Dust Emission	China Statistical Yearbook on Environment
Dust Stand_Rat	China Statistical Yearbook on Environment
Solid Waste	China Statistical Yearbook on Environment
Energy Consumption	China Statistical Yearbook, Energy Chapter
Output Value	China Statistical Yearbook, Industry Chapter
PPI	China Statistical Yearbook, Industry Chapter
Deflated Output	China Statistical Yearbook, Industry Chapter
Firm No	China Statistical Yearbook, Industry Chapter
Employees	China Statistical Yearbook, Industry Chapter
Δ Output	China Statistical Yearbook, Industry Chapter
Labour Intensity	China Statistical Yearbook, Industry Chapter
Export Intensity	China Statistical Yearbook, Industry Chapter
SOE share	China Statistical Yearbook, Industry Chapter
Foreign share	China Statistical Yearbook, Industry Chapter
Income Tax	China Statistical Yearbook, Industry Chapter

Table 3.18: VAT rebate reforms and data source

Policy reform	**Effective Date**	**Data Source**
Cai Shui (2006) No. 139	15th September 2006	China Customs
Cai Shui (2007) No. 64	15th April 2007	State Administration of Taxation (SAT)
Cai Shui (2007) No. 90	1st July 2007	SAT
Cai Shui (2007) No. 169	20th December 2007	SAT
Cai Shui (2008) No. 77	13th June 2008	China Customs
Cai Shui (2008) No. 111	1st August 2008	Ministry of Finance
Cai Shui (2008) No. 138	1st November 2008	China Customs
Cai Shui (2008) No. 144	1st December 2008	SAT
Cai Shui (2008) No. 177	1st January 2009	SAT
Cai Shui (2009) No. 14	1st February 2009	SAT
Cai Shui (2009) No. 43	1st April 2009	China Customs
Cai Shui (2009) No. 88	1st June 2009	China Customs

Table 3.19: Correlation Table: Trade policy measures, overall pollution intensities and resource dummy variables

	(1)														
	Overall	VAT t.	Export t.	Water	COD	Am.	Soot	SO2	Waste	Recycl.	Energy	Mineral	Metal	Wood	Stones
Overall	1.00														
VAT t.	0.90***	1.00													
Export t.	0.67***	0.28***	1.00												
Water	0.11***	0.17***	-0.04***	1.00											
COD	0.14***	0.20***	-0.04***	0.92***	1.00										
Am.	-0.02***	0.01	-0.06***	0.66***	0.56***	1.00									
Soot	-0.02***	0.00	-0.05***	0.40***	0.27***	0.42***	1.00								
SO2	0.04***	0.06***	-0.02***	0.38***	0.20***	0.39***	0.94***	1.00							
Waste	0.20***	0.14***	0.20***	0.05***	-0.07***	-0.01	0.31***	0.46***	1.00						
Recycl.	0.16***	0.23***	-0.03***	0.22***	0.25***	0.15***	-0.12***	-0.24***	-0.55***	1.00					
Energy	0.09***	0.11***	0.01**	0.25***	0.04***	0.36***	0.81***	0.88***	0.47***	-0.21***	1.00				
Mineral	0.29***	0.30***	0.13***	-0.03***	-0.07***	-0.06***	0.18***	0.23***	0.28***	0.01	0.17***	1.00			
Metal	0.25***	0.21***	0.20***	-0.08***	-0.11***	-0.13***	0.08***	0.20***	0.41***	-0.36***	0.35***	-0.08***	1.00		
Wood	0.14***	0.19***	-0.00	-0.04***	-0.01*	-0.03***	0.01	-0.03***	-0.05***	0.06***	-0.05***	-0.03***	-0.03***	1.00	
Stones	0.06***	0.08***	-0.01*	-0.03***	-0.03***	-0.04***	0.03***	0.04***	0.05***	-0.07***	0.04***	-0.03***	-0.03***	-0.01*	1.00

The pollutants repesents the overall pollution intensites, e.g. *Water*=Water Int. Other abbreviations: Overall=Overall, Am.=Ammonium Nitrogen, Recycl.=Recycling

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

Table 3.20: Overall export tax and pollution intensities

	(1) 2005-06	(2) 2007-2009
Water Reg_gap*Int	0.002	0.013 ∗ ∗
	(0.002)	(0.006)
COD Int	1.668∗∗∗	−0.236
	(0.455)	(1.693)
Ammonium N. Int	−16.255 ∗ ∗	−54.742 ∗ ∗
	(6.964)	(25.904)
Soot Reg_gap*Int	−4.127 ∗ ∗	−10.794
	(1.998)	(17.044)
SO2 Reg_gap*Int	1.569	2.913
	(1.086)	(4.627)
Waste Int	0.009∗∗∗	0.015∗∗∗
	(0.002)	(0.005)
Recycling Ratio	10.743 ∗ ∗	17.167
	(4.896)	(10.648)
Energy Int	−0.002	0.037∗∗∗
	(0.006)	(0.010)
Observations	11527	17147
r2	0.202	0.277
F	16.224	10.234

Cluster robust standard errors in parentheses

Dependent variable: Overall export tax

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

Table 3.21: VAT tax, export tax and pollution ranks, Year 2007

	VAT tax	export tax	Water	COD	A_N	Soot	SO2	Waste	Recycling	Energy
Artwork	6.7	0.0	13	21	22	11	15	19	10	22
Beverages	5.6	0.0	30	34	29	20	13	13	33	6
Chemical Fibres	6.3	0.0	32	32	31	26	26	18	31	27
Chemicals	7.7	0.1	31	26	35	30	28	26	21	34
Clothing	5.0	0.0	29	25	24	8	8	4	25	11
Coal	13.7	0.8	23	17	11	23	22	33	18	30
Communication Equipment	2.9	0.0	4	7	7	4	3	9	11	4
Culture, Sports	7.5	0.0	3	3	4	3	4	3	15	10
Electrical Equipemnt	3.8	0.0	9	12	15	15	21	27	4	17
Food Manufacturing	5.2	0.0	28	30	30	14	10	8	29	9
Food Processing	6.9	0.3	26	33	26	9	6	6	32	3
Furniture	6.7	0.0	10	18	21	12	11	16	14	12
General Machinery	2.6	0.0	6	4	5	13	17	24	5	19
Leather/Fur/Feather	11.2	0.0	27	29	34	6	5	5	20	5
Measuring Instruments	4.3	0.0	8	11	13	5	7	15	12	7
Medicine	5.4	0.0	24	28	25	17	14	7	27	8
Metal Products	8.1	0.2	15	14	12	25	25	29	6	29
Mining: Ferrous Metal Ores	13.0	10.0	22	10	6	29	31	35	1	26
Mining: Non-Ferrous Metal Ores	11.7	11.3	34	27	20	27	34	36	2	20
Mining: Nonmetal/ Other Ores	12.4	1.1	20	15	14	32	27	30	19	28
Natural Gas	15.9	0.7	2	2	3	7	12	11	13	18
Non-metalic Mineral Products	9.5	0.0	14	19	18	35	35	25	34	35
Paper	15.3	0.0	36	36	36	33	30	21	36	23
Petroleum, Nuclear Fuel	9.7	0.4	21	16	23	34	33	28	23	33
Plastic	8.7	0.0	19	23	32	24	24	17	22	24
Printing Media	5.2	0.0	35	35	33	21	18	12	30	13
Recycling/Disposal of Waste	13.9	6.0	1	1	1	1	1	1	17	1
Rubber	7.6	0.0	18	20	27	22	23	20	16	25
Smelting Ferrous Metals	11.9	1.6	16	9	16	31	29	32	7	36
Smelting Non-ferrous Metals	12.5	1.2	17	13	17	28	32	34	3	32
Special Machinery	3.0	0.0	7	6	9	16	19	23	9	21
Supply of Electricity	4.0	0.0	25	5	2	36	36	31	35	31
Textiles	5.8	0.0	33	31	28	18	20	10	28	16
Timber/Wood	14.7	0.3	11	22	19	19	16	14	24	14
Tobacco	8.7	0.0	12	24	8	2	2	2	26	2
Transport Equipemnt	1.4	0.0	5	8	10	10	9	22	8	15
Total	8.2	0.9	19	19	19	19	19	19	19	19

Columns 3 to 8 rank the industries according to their pollution intensities with respect to a particular pollutant.
A higher rank indicates a higher pollution intensity.
A_N gives the rank for the ammonium nitrogen intensity.

Table 3.22: Sensitivity analysis: Dependent variable export tax

	(1) Manufacturing	(2) Small	(3) No Reg_gap	(4) 2007
Water Reg_gap*Int	0.000	−0.003∗∗	−0.003∗	0.001
	(0.001)	(0.001)	(0.002)	(0.001)
Water Int				
COD Int	0.015	0.467	−0.001	0.041
	(0.268)	(0.308)	(0.316)	(0.285)
Ammonium N. Int	−10.438	−3.651	15.682	−17.560∗
	(9.619)	(14.948)	(13.177)	(9.276)
Soot Reg_gap*Int	−0.376	0.632	5.286	−3.951
	(2.549)	(3.969)	(3.970)	(2.678)
Soot Int				
SO2 Reg_gap*Int	−3.347∗∗∗	−2.998∗∗	−1.537∗	−2.430∗∗
	(1.060)	(1.173)	(0.862)	(1.037)
SO2 Int				
Waste Int	0.004	0.012∗∗∗	0.008∗∗∗	0.012∗∗∗
	(0.008)	(0.001)	(0.001)	(0.001)
Recycling Ratio	1.309	7.949∗∗	1.156	5.700∗∗∗
	(2.749)	(3.417)	(2.004)	(1.749)
Energy Int	−0.000	−0.009	−0.015∗∗	0.001
	(0.003)	(0.006)	(0.006)	(0.003)
Mineral	0.936∗	−0.273	−0.083	
	(0.512)	(0.467)	(0.327)	
Wood	−0.675	−1.081	−0.627∗	
	(1.070)	(0.755)	(0.359)	
Stones	−1.141∗	−0.973∗	−0.560	
	(0.571)	(0.515)	(0.382)	
Metal	0.471	1.687	1.545	
	(0.571)	(1.418)	(1.427)	
Primary	0.203	1.714∗∗∗	1.475∗∗	
	(0.409)	(0.480)	(0.549)	
L.Exp share [5-15)	−0.049		−0.279∗	
	(0.074)		(0.162)	
L.Exp share 15+	0.436∗		−0.005	
	(0.244)		(0.180)	
L.Employees	0.177	0.265∗	0.150	
	(0.121)	(0.147)	(0.144)	
L.Firm No	−0.054∗	−0.022	0.031	
	(0.031)	(0.032)	(0.033)	
L.Profits	0.006∗	0.001	−0.009	
	(0.003)	(0.003)	(0.006)	
L.Δ Output	0.757	3.883∗∗	−0.488	
	(1.939)	(1.792)	(1.900)	
L.Labour Intensity	−0.002	−0.010	−0.019	
	(0.011)	(0.030)	(0.013)	
L.Export Intensity	−29.278∗	−51.523	−32.539	
	(14.801)	(39.429)	(24.443)	
L.SOE share	0.150	0.481	1.233	
	(0.964)	(1.274)	(0.910)	
L.Foreign share	−1.287	1.525	1.189	
	(1.267)	(1.263)	(0.766)	
L.Income tax	−0.005	−0.004	−0.006	
	(0.010)	(0.010)	(0.010)	
VAT tax	0.124∗	0.143∗∗	0.154∗∗∗	
	(0.067)	(0.055)	(0.045)	
Tariff	−0.018	−0.019	−0.015	
	(0.023)	(0.024)	(0.014)	
Observations	14990	10787	5700	17147

Cluster robust standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 3.23: Sensitivity analysis: Dependent variable: export tax

	(1) No Reg_gap	(2) Direct	(3) Fixed pollution
Water Reg_gap*Int		−0.004	−0.002
		(0.002)	(0.002)
Water Int	0.000		
	(0.000)		
COD Int	−1.047	0.530	0.375
	(0.926)	(0.358)	(0.566)
Ammonium N. Int	−7.046	1.652	0.141
	(12.050)	(5.916)	(18.060)
Soot Reg_gap*Int		0.116	−2.433
		(1.555)	(7.456)
Soot Int	3.486		
	(3.344)		
SO2 Reg_gap*Int		−0.791	−4.357∗∗
		(0.627)	(1.742)
SO2 Int	−3.191∗∗		
	(1.449)		
Waste Int	0.007∗∗∗	0.006∗∗∗	0.009∗∗∗
	(0.001)	(0.001)	(0.001)
Recycling Ratio	1.314	3.772∗	1.255
	(1.851)	(1.958)	(0.972)
Energy Int	0.001	−0.006	−0.003
	(0.006)	(0.005)	(0.007)
Mineral	0.756	0.693	0.692
	(0.457)	(0.497)	(0.493)
Wood	−1.465∗∗	−1.428∗∗	−1.405∗∗
	(0.634)	(0.595)	(0.683)
Stones	−1.116∗∗	−0.963∗∗	−0.961∗∗
	(0.449)	(0.377)	(0.402)
Metal	1.563	1.573	1.435
	(1.385)	(1.443)	(1.015)
Primary	1.179∗∗∗	1.444∗∗∗	1.245∗∗
	(0.428)	(0.472)	(0.501)
L.Exp share [5-15)	−0.149	−0.219	−0.175
	(0.126)	(0.135)	(0.123)
L.Exp share 15+	0.314	0.218	0.263
	(0.268)	(0.255)	(0.258)
L.Employees	0.213	0.108	0.266∗
	(0.127)	(0.128)	(0.139)
L.Firm No	−0.038	−0.032	−0.058∗
	(0.028)	(0.033)	(0.030)
L.Profits	−0.000	0.003	0.002
	(0.003)	(0.003)	(0.003)
L.Δ Output	2.957∗	3.149∗	2.656∗
	(1.519)	(1.686)	(1.452)
L.Labour Intensity	−0.019	−0.021	−0.013
	(0.013)	(0.016)	(0.012)
L.Export Intensity	−52.773∗	−49.013	−36.451∗
	(30.435)	(31.847)	(19.918)
L.SOE share	1.082	−1.085	−0.086
	(1.282)	(1.026)	(0.757)
L.Foreign share	−0.282	−0.490	−0.533
	(0.952)	(1.102)	(0.949)
L.Income tax	−0.006	0.010	−0.002
	(0.009)	(0.011)	(0.008)
VAT tax	0.147∗∗∗	0.150∗∗	0.139∗∗
	(0.052)	(0.057)	(0.056)
Tariff	−0.029	−0.020	−0.022
	(0.021)	(0.019)	(0.020)
Observations	17022	17022	16954

Cluster robust standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Table 3.24: By year - Dependent variable: VAT tax

	(1) 2005	(2) 2006	(3) 2007	(4) 2008	(5) 2009
Water Reg_gap*Int	0.003	−0.004	0.009**	0.019***	0.028
	(0.003)	(0.005)	(0.004)	(0.006)	(0.020)
COD Int	1.465***	3.505***	−0.311	−3.503**	−6.880
	(0.498)	(1.057)	(1.089)	(1.483)	(4.707)
Ammonium N. Int	−5.939	−3.203	5.020	60.741**	177.210***
	(5.824)	(8.983)	(19.319)	(27.142)	(55.813)
Soot Reg_gap*Int	−1.189	−8.040***	−10.528	−17.263	−6.036
	(1.765)	(2.963)	(6.433)	(11.959)	(42.480)
SO2 Reg_gap*Int	−0.162	4.101***	4.916**	14.725***	24.709*
	(0.605)	(1.359)	(2.323)	(3.214)	(13.056)
Waste Int	0.001	−0.000	−0.008*	−0.010***	−0.010*
	(0.001)	(0.001)	(0.004)	(0.002)	(0.005)
Recycling Ratio	1.689	1.252	8.604	5.151	3.817
	(2.268)	(2.162)	(5.625)	(5.107)	(8.258)
Energy Int	0.006	0.007*	0.031***	0.047***	0.020
	(0.005)	(0.004)	(0.007)	(0.009)	(0.014)
Mineral	1.746***	3.004***	4.186***	5.013***	6.855***
	(0.478)	(0.412)	(0.683)	(0.802)	(0.921)
Metal	−0.600	1.661**	3.690***	4.390***	6.856***
	(0.593)	(0.654)	(1.318)	(1.617)	(2.139)
Wood	6.535***	6.884***	4.913***	8.296***	8.455***
	(0.752)	(0.787)	(0.712)	(0.995)	(0.955)
Stones	1.452	3.972***	2.167*	3.302***	5.444***
	(1.731)	(1.447)	(1.115)	(1.103)	(0.929)
Primary	0.856	1.487**	1.232	−0.336	−0.394
	(0.771)	(0.676)	(0.812)	(0.442)	(0.972)
L.Exp share [5-15)	0.111	0.003	0.278	−0.018	−0.702**
	(0.207)	(0.178)	(0.172)	(0.185)	(0.294)
L.Exp share 15+	0.237	0.026	0.252	−0.036	−0.712
	(0.312)	(0.407)	(0.280)	(0.372)	(0.434)
L.Employees	−0.068	−0.013	−0.330	−1.046**	−0.540
	(0.173)	(0.202)	(0.267)	(0.429)	(0.331)
L.Firm No	−0.067	−0.127**	−0.188***	−0.025	−0.034
	(0.048)	(0.056)	(0.062)	(0.065)	(0.052)
L.Profits	−0.001	0.013**	0.016**	0.005	−0.002
	(0.007)	(0.005)	(0.007)	(0.008)	(0.008)
L.Δ Output	3.901**	0.630	6.668*	−8.935	13.707***
	(1.636)	(0.485)	(3.448)	(5.873)	(4.207)
L.Labour Intensity	−0.005	0.036	0.060	0.069	0.036
	(0.012)	(0.033)	(0.044)	(0.048)	(0.103)
L.Export Intensity	16.654	35.177	60.581*	13.768	44.259
	(15.398)	(39.017)	(33.979)	(36.888)	(62.410)
L.SOE share	−4.328***	−5.965***	−9.976***	−7.824**	−9.029*
	(1.525)	(1.763)	(2.205)	(3.178)	(4.965)
L.Foreign share	−1.040	−2.591**	−5.259***	1.991	5.232
	(1.022)	(1.242)	(1.782)	(2.440)	(3.306)
L.Income tax	0.047*	0.055*	0.098***	0.054*	0.091***
	(0.028)	(0.030)	(0.031)	(0.030)	(0.035)
Export tax	0.633**	0.365***	0.256**	0.267***	0.247**
	(0.276)	(0.131)	(0.107)	(0.082)	(0.122)
Tariff	−0.017	−0.026*	−0.046**	−0.025	−0.021
	(0.010)	(0.013)	(0.018)	(0.023)	(0.028)
Observations	5690	5683	5700	5630	5624
r2	0.444	0.488	0.636	0.676	0.664
F	434.697	483.769	194.548	397.649	6380.176

Cluster robust standard errors in parentheses

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

Table 3.25: By year - Dependent variable: Export tax

	(1) 2005	(2) 2006	(3) 2007	(4) 2008	(5) 2009
Water Reg_gap*Int	−0.004*	−0.002	−0.003*	0.002	−0.000
	(0.002)	(0.001)	(0.002)	(0.002)	(0.005)
COD Int	0.410*	−0.035	−0.001	0.214	−0.527
	(0.242)	(0.266)	(0.316)	(0.539)	(1.516)
Ammonium N. Int	7.984	7.320	15.682	−33.895**	27.104
	(5.671)	(6.100)	(13.177)	(13.281)	(35.935)
Soot Reg_gap*Int	1.714	2.628	5.286	−0.213	8.947
	(1.372)	(1.689)	(3.970)	(4.758)	(22.424)
SO2 Reg_gap*Int	0.369	−0.409	−1.537*	−7.124***	−11.445*
	(0.305)	(0.335)	(0.862)	(2.045)	(6.547)
Waste Int	0.002	0.004***	0.008***	0.010***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Recycling Ratio	0.622	2.554***	1.156	1.504	−0.958
	(1.243)	(0.850)	(2.004)	(1.584)	(3.780)
Energy Int	−0.010**	−0.006*	−0.015**	0.002	−0.007
	(0.005)	(0.003)	(0.006)	(0.004)	(0.008)
Mineral	−0.408	−0.367*	−0.083	1.135*	1.414*
	(0.291)	(0.198)	(0.327)	(0.664)	(0.793)
Metal	1.102	1.034	1.545	0.251	1.311
	(1.094)	(0.985)	(1.427)	(0.585)	(1.711)
Wood	−1.285*	−0.808**	−0.627*	−0.487	−1.862**
	(0.658)	(0.306)	(0.359)	(0.843)	(0.892)
Stones	−0.376	−0.621	−0.560	−1.029	−1.333**
	(0.283)	(0.484)	(0.382)	(0.624)	(0.574)
Primary	0.391	0.559**	1.475**	0.490	1.483***
	(0.367)	(0.262)	(0.549)	(0.482)	(0.386)
L.Exp share [5-15)	−0.163	−0.110	−0.279*	−0.102	−0.033
	(0.111)	(0.116)	(0.162)	(0.126)	(0.149)
L.Exp share 15+	−0.145	−0.001	−0.005	0.546*	0.448
	(0.103)	(0.113)	(0.180)	(0.309)	(0.331)
L.Employees	−0.120	0.014	0.150	0.123	0.420**
	(0.103)	(0.062)	(0.144)	(0.228)	(0.200)
L.Firm No	0.028	0.047	0.031	−0.074**	−0.072**
	(0.043)	(0.032)	(0.033)	(0.030)	(0.032)
L.Profits	0.004	−0.005	−0.009	0.010*	−0.003
	(0.004)	(0.005)	(0.006)	(0.005)	(0.004)
L.Δ Output	1.499*	1.296***	−0.488	−1.523	3.395*
	(0.868)	(0.218)	(1.900)	(3.708)	(1.782)
L.Labour Intensity	0.012	−0.006	−0.019	0.004	−0.025
	(0.011)	(0.009)	(0.013)	(0.015)	(0.022)
L.Export Intensity	−12.577**	−28.405**	−32.539	−52.143***	−65.337
	(4.734)	(11.637)	(24.443)	(17.639)	(44.389)
L.SOE share	−0.716	1.351	1.233	−3.094**	−0.593
	(0.830)	(0.992)	(0.910)	(1.277)	(1.922)
L.Foreign share	−0.815	1.616**	1.189	−2.581**	−1.649
	(0.571)	(0.779)	(0.766)	(0.971)	(1.998)
L.Income tax	0.017	−0.003	−0.006	0.017	−0.001
	(0.017)	(0.008)	(0.010)	(0.012)	(0.016)
VAT tax	0.142	0.117**	0.154***	0.111	0.160*
	(0.088)	(0.054)	(0.045)	(0.068)	(0.079)
Tariff	−0.007	−0.006	−0.015	−0.020	−0.025
	(0.006)	(0.009)	(0.014)	(0.019)	(0.027)
Observations	5690	5683	5700	5630	5624
r2	0.134	0.132	0.214	0.269	0.215
F	3.375	18345.135	16.539	508.772	74.586

Cluster robust standard errors in parentheses

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

Table 3.26: By year - Dependent variable: Import tariff

	(1) 2005	(2) 2006	(3) 2007	(4) 2008	(5) 2009
Water Reg_gap*Int	0.027***	−0.007	−0.001	0.014	0.015
	(0.006)	(0.015)	(0.007)	(0.012)	(0.028)
COD Int	−5.429***	0.604	−1.193	−6.011**	−4.475
	(1.089)	(3.111)	(1.870)	(2.698)	(6.082)
Ammonium N. Int	−27.981	11.156	33.809	26.919	−77.372
	(18.889)	(23.316)	(30.766)	(31.184)	(48.095)
Soot Reg_gap*Int	−4.253	8.752*	13.812	−6.003	−102.897**
	(4.762)	(5.161)	(9.402)	(18.000)	(41.160)
SO2 Reg_gap*Int	−0.995	2.467	−3.200	7.093	37.598***
	(1.796)	(2.788)	(3.846)	(4.762)	(13.452)
Waste Int	−0.001	0.003	0.006	−0.003	0.005
	(0.002)	(0.002)	(0.007)	(0.003)	(0.005)
Recycling Ratio	7.616	9.067*	9.597	18.645**	30.870***
	(6.181)	(4.979)	(10.548)	(7.800)	(7.167)
Energy Int	0.013	−0.025*	−0.015	−0.006	0.003
	(0.013)	(0.013)	(0.013)	(0.014)	(0.014)
Mineral	−2.992	−2.343	−1.340	−2.207	−3.013
	(1.863)	(1.633)	(1.332)	(1.517)	(1.976)
Metal	1.356	2.295*	1.922	1.552	−0.143
	(1.092)	(1.203)	(1.323)	(1.025)	(1.374)
Wood	−7.597***	−7.361***	−7.398***	−11.414***	−9.330***
	(1.631)	(1.568)	(1.588)	(1.779)	(1.341)
Stones	1.220	2.560	1.795	2.662	1.503
	(4.301)	(4.362)	(4.846)	(5.002)	(4.639)
Primary	−0.764	−0.485	−1.578	−0.986	−2.319
	(1.099)	(1.415)	(1.524)	(1.196)	(1.408)
L.Imp share [5-15)	−1.766***	−1.905***	−2.040***	−1.990***	−1.746***
	(0.490)	(0.524)	(0.520)	(0.472)	(0.476)
L.Imp share 15+	−1.310*	−1.673**	−2.073***	−1.866**	−2.275***
	(0.646)	(0.786)	(0.681)	(0.756)	(0.655)
L.Employees	−0.346	−1.090**	−1.339***	−0.304	−0.973***
	(0.466)	(0.431)	(0.455)	(0.685)	(0.312)
L.Firm No	0.102	0.155	0.147	−0.030	0.069
	(0.133)	(0.145)	(0.149)	(0.095)	(0.062)
L.Profits	0.010	0.028**	0.017*	−0.001	0.011*
	(0.023)	(0.014)	(0.009)	(0.016)	(0.006)
L.Δ Output	−13.033***	−2.994***	−0.963	18.493*	6.038*
	(3.965)	(1.099)	(8.084)	(10.568)	(3.433)
L.Labour Intensity	0.096*	0.100*	0.152***	0.167**	0.155***
	(0.052)	(0.056)	(0.051)	(0.071)	(0.057)
L.Import Intensity	−3.625	−30.890	−41.600*	−85.136***	−58.518**
	(6.720)	(28.364)	(20.889)	(24.246)	(23.353)
L.SOE share	−12.954***	−21.047***	−24.183***	−16.729***	−23.397***
	(2.718)	(4.970)	(4.537)	(4.900)	(4.446)
L.Foreign share	1.503	−2.018	−4.056	1.922	3.298
	(2.427)	(4.644)	(5.065)	(4.017)	(3.687)
L.Income tax	0.402***	0.467***	0.426***	0.259***	0.275***
	(0.040)	(0.087)	(0.055)	(0.046)	(0.045)
Overall export tax	−0.138***	−0.111*	−0.185***	−0.099**	−0.079
	(0.050)	(0.056)	(0.058)	(0.040)	(0.048)
Observations	5690	5683	5700	5630	5624
r2	0.270	0.258	0.265	0.277	0.273
F	72.711	157.628	87.557	161.477	74.043

Cluster robust standard errors in parentheses

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

4 International trade and fisheries management: An empirical analysis

Abstract

This chapter analyses the factors which affect a government's decision to introduce catch share programs for fisheries. A particular focus is on the role of international trade in fisheries products. We investigate the link between fisheries management, the price of fish, openness to international trade and a range of country and fishery characteristics. The empirical evidence provides robust evidence of a negative relationship between the price and the introduction of catch share programs. However, the management decision does not seem to depend on the percentage of the domestic catch which is traded.

4.1 Introduction

This chapter studies the factors which motivate governments to introduce catch share programs for fisheries. Catch share programs are fisheries management tools which allocate secure fishing privileges to individual entities. The majority of the catch share programs analysed in this chapter of the thesis are quota-based catch share programs, which allocate the right to fish a certain percentage of a total allowable catch to individuals, groups or vessels. In other words, the government determines the total allowable catch for a particular fish species and the fisherman or the fishing vessel is not allowed to harvest more than its quota, which is equivalent to a share of the total allowable catch.

Catch share programs can also be area-based. Area-based catch share programs are also known as Territorial Use Rights for Fishing programs (TURFs) and allocate the privilege to fish in specific areas to groups or individuals. However, this type of catch share program is less prevalent and only plays a minor role in the context of this chapter.

This chapter studies the government's decision to introduce a catch share program for a particular fish species. We investigate empirically which factors foster or hinder the introduction of catch share programs but we do not analyse their effect on the fishery.

A special focus of this chapter is on the effect of international trade and exports of fisheries products on fisheries management. Research on the effect of trade on the introduction of catch share programs is not only of academic interest but also of high policy relevance. Fisheries products have become a highly traded commodity. According to FAO (2008), nearly 40 percent of global fish production is traded. The total value of trade in fisheries products increased from 8 billion US$ in 1976 to 130 billion US$ in 2011.[1] According to Asche and Smith (2009), this increase in the trade of seafood products can be attributed to improved storage and preservation technologies as well as lower transport cost.

At the same time fisheries collapse is a widespread phenomenon. According to Worm et al. (2006), about 27% of the world's fisheries were collapsed[2] by 2003 and the percentage of collapsed fisheries is increasing. It is obvious that the world's fisheries need to be managed in a more sustainable way. Catch share programs have turned out to be successful instruments in

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[1] Author's calculations based on data by the FAO.

[2] Worm et al. (2006) define a fishery as collapsed in year t if the catch in that year is less than 10 percent of the maximum catch since 1950.

avoiding fisheries collapse (Costello et al., 2008). Hence, a study of the factors which motivate a government to introduce catch share programs can give important insights for the sustainability of the world's oceans.

Several theoretical papers link the management of renewable resources to exports of fisheries products. The literature focuses on small exporters of fisheries products and models a country's opening up to trade as an exogenous increase in the (relative) price of fish. Several mechanisms via which this change in the price can affect resource management were proposed by the literature. In Sethi and Somanathan (1996)'s evolutionary game-theoretic framework, harvesting restrictions are based on social norms. Sethi and Somanathan (1996) show that an exogenous increase in the price, which could be caused by opening up to trade, can lead to the collapse of social norms and resource management. Barbier et al. (2005) analyse the effect of trade openness on resource management in an environment with a corrupt regulator. As the price for the resource increases, firms have higher benefits from bribing the government for larger harvesting quotas. Opening up to trade can, thus, increase resource extraction and deteriorate management. Another stream of the literature holds that a higher price could lead to the introduction of property rights or harvesting restrictions (Demsetz, 1967; Copeland and Taylor, 2009) or to the enforcement of existing property rights (Hotte et al., 2000; Tajibaeva, 2012).

With such conflicting theoretical predictions, empirical evidence is necessary to shed light on the relationship between trade and the management of a renewable resource. To the best of our knowledge, there is no existing empirical analysis on the link between international trade and the management of a renewable resource. The analysis in this chapter of the thesis tries to fill this gap using fisheries data.

In order to be able to study the effect of trade on fisheries management, we assemble a large and unique dataset. The dataset contains information on the adoption of catch share programs, prices, landings as well as trade patterns at the country-species level. Moreover, it includes a large number of country-level indicators including the number of fishermen, technology and regulatory quality. The analysis is based on data from 86 countries from all continents and all income groups. The dataset spans the time period from 1983 to 2003.

The analysis is centred around the factors which motivate a government's initial decision to introduce catch share programs. In other words, we investigate when and why a government introduces a fishing quota or a

TURF program.[3] This is best modelled using survival analysis.

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

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

We also control for other factors which determine the introduction of catch share programs. The choice of our control variables is based on the theoretical model by Copeland and Taylor (2009) as well as anecdotal evidence. The results reveal that overcapacity in a fishery is not conducive to fisheries management. Fisheries with a large number of fishermen or with access to small fishing grounds are less likely to be managed. Moreover, good governance seems crucial for the introduction of catch share programs.

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[3] We are agnostic about the fisheries management tool which was in place prior to the introduction of the catch share program, since we do not know whether the fishery was an open access fishery or whether it was managed using other fisheries management tools before it introduced quotas or TURF programs.

Corrupt countries are significantly less likely to introduce these rights-based management tools. Governments are also less likely to introduce catch share programs for fisheries which have collapsed. This corroborates the previous two points since fisheries collapse is a sign of both overcapacity in the fishery and poor governance.

This chapter is structured as follows. Section 4.2 reviews the relevant literature. The theoretical literature which motivates this analysis is explained in Sections 4.2.1 and 4.2.2, where Section 4.2.1 discusses the papers which argue that an exogenous increase in the price is harmful to resource management and Section 4.2.2 explores the literature which argues that an increase in the price can be beneficial for resource management. Empirical evidence on the characteristics of countries and fisheries which introduce catch share programs is discussed in Section 4.2.3 along with anecdotal evidence on individual countries' motivation to introduce catch share programs.

Section 4.3 explains our empirical strategy and the choice of the control variables. The construction of the dataset is described in Section 4.4.

Due to the sparsity of previous empirical work on catch share programs, Section 4.5 describes the fisheries which introduce catch share programs in detail. Section 4.5.1 shows that catch share programs are used by numerous countries including a few developing countries. A broad spectrum of species is managed via catch share programs, as highlighted in Section 4.5.2. Section 4.5.3 shows in which years the programs were adopted and Section 4.5.4 demonstrates that quota programs are the most prevalent type of catch share programs in our dataset.

Section 4.6 provides summary statistics and compares the characteristics of the fisheries which introduce catch share programs to the characteristics of non-adopters.

The results for our baseline regression are described in Section 4.7 and Section 4.8 tests the sensitivity of those results. We introduce individual heterogeneity and fixed effects in Sections 4.8.1 to 4.8.3. Further robustness checks in Sections 4.8.4 and 4.8.5 address concerns about measurement errors or reverse causality.

The empirical analysis in this chapter reveals a robust negative relationship between the price and the introduction of catch share programs. Section 4.9 investigates whether this finding is in line with existing theoretical models and discusses mechanisms which can potentially explain a negative relationship between the price and the introduction of catch share programs. Those explanations include cost differences, social norms and rent-seeking.

In the main part of this chapter, trade openness is modelled through the price. Section 4.11 examines the relationship between the introduction of catch share programs and other proxies for trade openness. Finally, Section 4.12 concludes.

This chapter contains an appendix with additional information on the construction of the dataset in Section 4.13.1. Section 4.13.2 provides stylized facts on the fisheries which introduce catch share programs and Section 4.13.3 shows further results and robustness tests.

4.2 Literature Review

Several theoretical papers link trade openness to the management of renewable resources. All of these papers study small exporters of fisheries products and model the removal of trade barriers as an exogenous increase in the price of fish. The predicted effect of an exogenous increase in the price on resource management differs significantly across those papers. This section provides a brief summary of the relevant papers and the suggested channels via which trade affects resource management.

4.2.1 Papers which suggest that trade has a negative effect on resource management

Sethi and Somanathan (1996) and Barbier et al. (2005) argue that an exogenous increase in the price has a negative impact on resource management. The two papers draw up different mechanisms via which the price affects resource management.

In Sethi and Somanathan (1996)'s evolutionary game-theoretic framework, harvesting restrictions are based on social norms. Sethi and Somanathan (1996) show that an exogenous increase in the price, which could be caused by opening up to trade, can lead to the collapse of social norms and resource management.

Barbier et al. (2005) analyse the effect of an exogenous change in the price on management of a non-renewable resource in an environment in which the regulator is corrupt. In their paper, the government's objective function puts weight on both social welfare and bribes. As the price for the resource increases, firms have higher benefits from bribing the government for larger quotas. Opening up to trade and exporting can thus increase resource extraction and deteriorate management.[4]

4.2.2 Papers which suggest that trade openness improves management

The papers by Demsetz (1967), Hotte et al. (2000), Copeland and Taylor (2009) and Tajibaeva (2012) suggest that trade has a positive effect on resource management if the price for the renewable resources increases as the country opens up to trade. The channels via which this increase in the price affects resource management differ across the papers.

Hotte et al. (2000) develop a framework in which property rights exist, but the enforcement of property rights is costly. In this scenario, an increase in the price can lead to the enforcement of property rights. However, the country might lose from trade due to the enforcement costs.

Another model with costly enforcement of property rights was developed by Tajibaeva (2012). In her model, an export-oriented resource service sector, such as ecotourism, needs to enforce its property rights over the resource against poachers. Tajibaeva (2012) calibrates the model to Tanzania and analyses the effect of changes in the terms of trade on property rights enforcement and the resource stock. She finds that the enforcement of property rights improves as the terms of trade improve.

While Hotte et al. (2000) and Tajibaeva (2012) model the effect of trade on the *enforcement* of property rights, Demsetz (1967) and Copeland and Taylor (2009) study the link between trade and the *introduction* of property rights.

Demsetz (1967) argues that externalities exist since the cost of the internalization exceeds the gains from internalization. In other words, externalities exist because of large transaction costs. By making a good more valuable, exporting can lead to the adoption of resource management. If the price increases, the gains from internalising property rights might exceed the cost and resource management might be introduced.

The model by Copeland and Taylor (2009) is most suitable for capturing

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[4] The theoretical model is applied to deforestation. Barbier et al. (2005) find that an increase in the terms of trade reduces agricultural land expansion (or deforestation). This is opposed to the predictions of their model, but it suggests that opening up to trade might improve resource management. However, the results need to be taken with a grain of salt. The terms of trade are measured by an "index of export and import prices" (Barbier et al., 2005, p. 288). It is not entirely clear what this index contains, but the terms of trade do not capture the price of wood products. Therefore, the results do not inform us about the relationship between the price of a renewable resource and its management.

the introduction of catch share programs. This model is described in slightly more detail since it also motivates the choice of our control variables. In Copeland and Taylor (2009)'s model, the responsibility to manage the resource is not in the hands of private agents (as in Hotte et al., 2000), but rather in the hands of the government. Even though the model applies to renewable resources in general, we explain the model in the context of fisheries. In the model, the government limits fishing effort. But there is a moral hazard problem. Individuals have an incentive to cheat and fish more. If they are caught, they face a punishment, which is the withdrawal of the fishing licence.

Governments can only limit fishing effort if the restrictions satisfy the incentive constraint and generate non-negative profits. If the harvesting restrictions which satisfy the incentive constrain lead to negative profits, the fishery remains unregulated with de facto open access. Harvesting restrictions which satisfy the incentive constraint and generate positive profits for the fishermen are more likely if the government's enforcement power is high, the price is high and overcapacity is low. Overcapacity measures the pressure on the resource and depends on country and fisheries characteristics. Overcapacity is larger the higher the labour force that could go fishing, the better the harvesting technology and the lower the resource growth rate.

All economies exhibit open access at very low resource prices. If overcapacity is low and enforcement power is high, countries adopt restricted resource management as the price increases. This means that the price does not necessarily have a direct effect on resource management. The effect of trade on resource management depends on country- and species-specific variables.

4.2.3 Empirical and anecdotal evidence

The theoretical predictions concerning the effect of an exogenous increase in the price on resource management differ considerably. Hence, empirical evidence is needed to identify whether an increase in the price fosters or hampers the management of renewable resources. To the best of our knowledge, this chapter provides the first comprehensive analysis of the relationship between the price, as well as other proxies for trade openness, and the adoption of catch share programs.

A few case studies shed light on the relationship between trade and the management of renewable resources. They come to very different conclusions. According to Demsetz (1967), fur trade lead to the development of property rights amongst American Indians, since it increased the value of furs. Copeland and Taylor (2009) also mention the geoduck fishery in British Columbia as an example for a positive effect of trade on resource management. The geoduck fishery experienced high export demand from Asia and managed the transition from an open access fishery to a fishery with individual catch limits.

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

Finally, a thorough case study by Fenske (2014) argues that communities can abandon individual harvesting rights when exporting raises the price of a renewable resource. Fenske (2014) links palm oil exports in Nigeria in the late 19th and early 20th century to property rights to harvest palm trees. He argues that the Igbo in Nigeria responded to the increase in the price of palm oil by shifting from private harvesting rights to communal harvesting, since the monitoring costs are lower if the palm trees are communally harvested. It is noteworthy, however, that communal harvesting is not equivalent to an open access situation. Even under communal harvesting, there were strict rules which determined when individuals could collect the fruit of the palm tree.

In addition to the case studies, an analysis of catch share programs in developing countries gives a first idea of the relationship between trade and fisheries management. Jardine and Sanchirico (2012) compare the characteristics of developing countries which use catch share programs to the characteristics of developing countries which do not use right-based approaches to fisheries management. They find that the total value of fisheries exports at the country level is higher in developing countries which use catch share programs.

Moreover, Jardine and Sanchirico (2012) study the price category of fish species which are managed using catch share programs. The data on the price category are from the FishBase dataset and show that 12 species are in the low price category, 11 species are in the medium price category. Only 4 and 7 species achieve a high price and very high price respectively. Jardine and Sanchirico (2012)'s findings reveal that the largest number of fish species which introduce catch share programs are in the low or medium price category. This would suggest a negative relationship between the price and resource management.[5] This is consistent with our empirical evidence, which reveals that lower-price species are more likely to introduce catch share programs. However, Jardine and Sanchirico (2012) point out that "7 of the 12 fish species in the low price category are forage fish which are harvested in large volumes" (Jardine and Sanchirico, 2012, p. 1251). Hence, they argue that those fish species are valuable despite the low price. Due to the cost of setting up and enforcing catch share programs, Jardine and Sanchirico (2012) hold that fisheries which do not generate a high value would not necessarily benefit from the adoption of catch share programs.

However, Jardine and Sanchirico (2012)'s work differs from ours in one important way. We study the factors which determine the introduction of catch share programs. The panel nature for our dataset allows us to investigate the features of fisheries which adopt catch share programs at the point in time in which the catch share programs are introduced. Those feature are then compared to the characteristics of fisheries which do not introduce catch share programs. This allows us to study the factors which determine the introduction of catch share programs. Jardine and Sanchirico (2012), on the other hand, compare fisheries at the end of the sample period in 2008 or 2009. As pointed out in their paper, this does not allow them to infer whether factors like the price or the export value affect a government's decision to introduce catch share programs due to reverse causality. The introduction of catch share programs could lead to long-term adjustments in the fishery and affect the price and the export value. Using data from the point in time in which the catch share programs were introduced mitigates

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[5] In their paper, Jardine and Sanchirico (2012) come to a different conclusion. They argue that "the majority of fish species receive medium to very high prices [...]." Jardine and Sanchirico (2012, p. 1251)

this problem.[6]

Empirical and anecdotal evidence on the effect of trade on resource management is sparse and inconclusive. A thorough empirical analysis of the relationship between the price, trade openness and the introduction of catch share programs is, thus, an important contribution of this paper. However, our study is not limited to the relationship between trade and resource management. The goal of this paper is to investigate which factors motivate governments to introduce catch share programs. Anecdotal evidence on fisheries management provides first insights into the factors which affect a government's management decision.

Since the 1950s, a lot of fisheries have developed overcapacity which resulted in large pressure on fish stocks. Several countries have introduced catch share programs in response to declining stocks. These countries include Canada (Parsons, 2010), Iceland (Matthiasson and Agnarson, 2010) and New Zealand (Connor and Shallard, 2010). Moreover, the introduction of the TURF program in Chile was a response to severe overfishing in the *loco* fishery (San Martín et al., 2010).

However, not all countries have transitioned to the use of catch share programs when fish stocks were under pressure. Weak governance, concerns about employment in fishing communities as well as international trade are highlighted as important hindrances to fisheries management.

Especially in the developing world, weak governance and corruption seem to be major obstacles for the introduction of catch share programs. Williams and Staples (2010) describe fisheries management in South East Asia and argue that "government fisheries agencies are often given low national priority, corruption in fisheries is common, information systems are weak, and the countries lack coherent whole-government and whole-society approaches" (Williams and Staples, 2010, p. 240). According to Satia and Jallow (2010), weak governance and the lack of enforcement tools also hinder fisheries management in West Africa and Nandakumar and Nayak (2010) highlight that a powerful lobby of trawler agents impede the introduction of management in India.[7]

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[6] Our work improves on Jardine and Sanchirico (2012)'s analysis in a few other ways. First of all, our analysis is not restricted to developing countries. Secondly, we have trade and price data at the species level. Therefore, we can study the effect of trade in fisheries products of a particular species on the management of that species. Thirdly, our dataset contains information on the price of all fish species and not just the fish species which introduce catch share programs. This allows us to compare the adopters of catch share programs to the non-adopters.

[7] Jardine and Sanchirico (2012)'s finding that developing countries which use catch share programs have higher World Governance Indicators in 2008 or 2009 fits well

Fisheries are often a key employer, especially in remote areas. Fisheries policy can, thus, be characterised by an attempt to secure employment and the wages of fishermen even in countries like Norway (Steinshamn, 2010) or the United Kingdom (Pascoe and Tingley, 2010).

Governments in poor countries may be even more wary of catch limits, since fisheries do not only guarantee employment but are also crucial for food security. Satia and Jallow (2010) identify poverty as a key obstacle to fisheries management in West Africa and Nandakumar and Nayak (2010) argue that alleviation of poverty, employment and food security contributed to the expansion of fisheries in India. This expansion was not accompanied by fisheries management.

4.3 Empirical strategy

Our research studies a country's decision to introduce catch share programs. We model the time it takes the government to adopt a catch share program using survival analysis. Survival analysis is expedient for the purpose of our study since it allows us to focus on a government's initial decision to introduce rights-based management approaches.[8] In our dataset, we observe every fishery until it has introduced a catch share program. Fisheries which do not introduce catch share programs are observed until the end of the sample period.

With this data structure, the dependent variable in our analysis is a hazard rate.[9] In the context of our analysis, the hazard rate is defined as the probability that a fishery adopts management in year t conditional on survival up to year t (or conditional on not having adopted management after $t-1$ years).

The data used for this analysis are annual data. Hence, the analysis needs to be based on a discrete time model. We use a complementary log-log model, which is the discrete time version of a proportional hazards model.[10]

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with the notion that good governance is crucial for successful fisheries management. Since corruption varies more across countries than within countries across time, this probably implies that adopters of catch share programs had better governance at point in time in which the catch share programs were introduced.

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

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

[10] The logit model would be an alternative to the cloglog model. Section 4.13.3.2 in the Results Appendix shows that our results are not sensitive to the choice of the functional form.

Proportional hazard models are based on a separability assumption. The hazard θ is given by

$$\theta(t, X) = \theta_0(t) exp(\beta' X) \tag{4.1}$$

The baseline hazard $\theta_0(t)$ is only a function of the time t but not of the covariates. This means that the baseline hazard is common to all country-species. The country-species-specific function $exp(\beta' X)$ scales the baseline hazard.

Proportional hazard models have a convenient interpretation since absolute changes in the coefficient X imply proportionate changes in the hazard rate at each t. In other words, the coefficient estimates represent the elasticity of the hazard rate with respect to a one unit change in the coefficient estimate.

In the complementary log-log model, the hazard rate takes the form

$$h(t, X) = 1 - exp[-exp(\beta' X + \gamma_t)] \tag{4.2}$$

where γ_t can be thought of as the baseline hazard for year t. To be more precise, γ_t, is the difference in the integrated hazard at the end of year t and at the beginning of year t.

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

4.3.1 Price

The theoretical literature models trade openness as an increase in the price of the renewable resource. Following that literature, our main interest is in the relationship between the price and a government's decision to introduce catch share programs.[11]

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[11] Section 4.11 uses data on trade and domestic landings to analyse the effect of trade openness on catch share programs. Due to incomplete data coverage of trade data at the species level, we use the price in our baseline specification.

We use ex-vessel price data for all countries from Swartz et al. (2012). Prices are measured in constant 2005 US$ and the data are available at the species level. This disaggregate information on prices allows us to exploit variation within countries across species, within species across countries[12] and within country-species across time. The baseline model exploits all types of variation, especially since the theoretical models could apply to all types of variation. In the sensitivity analysis, we introduce random and fixed effects.

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

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

Our choice of control of variables is based on the anecdotal evidence presented in Section 4.2.3 and Copeland and Taylor (2009)'s model, which provides insights on the country and species characteristics which can affect the decision to introduce catch share programs.

4.3.2 Overcapacity in the fishery

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

The first component of overcapacity is the labour force which could potentially go fishing. A larger potential labour force increases pressure

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[12] Prices can vary across countries due to trade barriers such as import tariffs and export taxes as well as transport cost. Asche and Smith (2009) points out that perishability was a major constraint to trade in seafood products. However, improved storage and preservation technologies and cheaper transportation have dramatically increased fish trade over the last 30 years." (Asche and Smith, 2009, p. 7)

on the resource and makes management less likely. Hence, Copeland and Taylor (2009) predict a negative relationship between the labour force that could go fishing and the introduction of quotas. Anecdotal evidence also suggests that governments are concerned about employment in remote coastal communities. Hence, governments in countries with a large number of fishermen may be more wary about introducing catch limits.

We use data on the number of fishermen at the country level to measure the labour force that could potentially go fishing. The number of fishermen is measured in thousands.

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

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

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

4.3.3 Fisheries collapse

The anecdotal evidence suggests that several countries have introduced catch share programs in response to declining fish stocks. We want to account for this motive in the empirical analysis. Scientific evidence on fish stocks is sparse.[13] However, it is common practise to infer fisheries collapse from landings statistics. Following Worm et al. (2006) and Costello et al. (2008), we define a fishery j in country i as collapsed in year t if the catch in that year is less than 10 percent of the maximum catch since 1950. The catch data used to define a fishery as collapsed are from Swartz et al. (2012), who use data from the *Sea Around Us* catch database. The latter database maps landings to the origin of the catch on a spatial grid of the ocean based on individual country's landings statistics, information on foreign access to a country's Exclusive Economic Zone as well as distribution of fish species.[14] Since the Sea Around Us data map the landings to the country's EEZ, they allow us to identify whether landings within one country have declined drastically.

We do not have strong priors concerning the relationship between the introduction of management and fisheries collapse. On the one hand, it is possible that governments use catch share programs as a last resort once other attempts at managing the fishery have failed and the fishery has collapsed. In that case, a collapsed fishery would be more likely to be managed.

On the other hand, governments may recognise the potential of rights-based management approaches and adopt catch share programs as a logical consequence of a successful history of managing a particular fishery with other instruments. In the latter case, the percentage of fisheries which have collapsed prior to the introduction of management might be small.

4.3.4 Regulatory quality and enforcement power

The anecdotal evidence presented in Section 4.2.3 highlights weak governance and corruption as important obstacles for fisheries management. Our set of control variables, thus, includes a corruption indicator from the PGR Groups's International Country Risk Guide (ICRG). The ICRG provides corruption data on 140 developed, emerging and frontier markets from 1984

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

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

onwards.

In its assessment of corruption, the PGR group assigns each country risk points. A higher number of risk points indicates a lower risk. In order to make the interpretation of our coefficient estimates more intuitive, we rescale the corruption variable such that a higher value represents higher corruption.

The corruption indicator is an important variable for the purpose of our analysis, since corruption can hinder the implementation of catch share programs in two ways. First of all, fishermen may lobby against the introduction of catch share programs or bribe officials for large quotas. Lobbying is likely to be more severe in corrupt countries. Secondly, compliance with catch limits needs to be monitored. In highly corrupt countries, fishermen could bribe the monitoring authorities in local ports to misreport landings and catch a larger amount of fish than they are allowed to catch under their catch limits. Corruption is, thus, associated with low enforcement power. Copeland and Taylor (2009) show that low enforcement power can hinder the introduction of catch limits in an environment with imperfect monitoring. If enforcement power is low, it is difficult for the government to introduce catch limits that fishermen comply with. Based on those theoretical predictions and on the anecdotal evidence, we expect to find a negative relationship between corruption and the adoption of catch share programs.

4.3.5 Resources

Countries differ in their resource abundance and it is possible that resource abundant countries have more experience in managing resources. In that case, countries may be more prone to introduce catch share programs if resources contribute a larger proportion to their GDP. On the other hand, the abundance of other resources such as oil could imply that fisheries are considered less important for the domestic economy. This may reduce the government's incentive to manage them sustainably. We use data on resource rents as a percentage of GDP from the World Development Index to measure resource abundance. Resource rents are defined as the sum of oil, natural gas, coal, mineral and forest rents.

4.3.6 GDP per capita

In poor countries, commercial and subsistence fisheries are not only a source of employment but also contribute to food security. Therefore, governments in poor countries may be hesitant to introduce catch limits. Moreover, the countries with a higher income may have a higher demand for environmental quality and healthy fish stocks.[15] Both factors suggest that countries with a higher GDP per capita are more likely to introduce catch share programs.

GDP per capita is positively correlated with the corruption indicator as well as our measure for technology. If income per capita has a direct effect on the adoption of catch share programs, it is necessary to include the variable as a control variable. We use data on GDP per capita, measured in thousands of constant 2005 US$, from the World Development Indicators.

4.3.7 Estimating equation

The factors which where outlined in the previous few paragraphs motivate the estimating equation which is described in this section. We model the likelihood that a country i adopts fisheries management for species j in year t, given survival up to time $t-1$, as a function of the price in period $t-1$, p_{ijt-1}, and a range of country and species specific control variables. This motivates the following estimating equation:

$$\begin{aligned}\theta_{jit}(t,X) = F(&\beta_1 p_{jit-1} + \beta_2 \text{Fishers}_{jt} + \beta_3 \text{Agri VA}_{jt} + \beta_4 \text{Growth}_i + \\ &\beta_5 \text{Coastline}_j + \beta_6 \text{Collapsed}_{ijt} + \beta_7 \text{Corruption}_{jt} + \\ &\beta_8 \text{Resource Rents}_{jt} + \beta_9 \text{GDP pc}_{jt} + \gamma_t + v_{jit})\end{aligned} \tag{4.3}$$

where θ_{jit} is the hazard rate, γ_t represents the baseline hazard and v_{jit} is the error term. Table 4.1 provides a definition of the control variables and the units of measurement.

4.4 Data

This chapter uses data from a range of sources and the construction of the dataset is an important contribution of this chapter. This section describes the dataset. A summary of the data source is provided in Table 4.1.

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

Table 4.1: Variable definition

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

4.4.1 Management data

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

Since the information on catch share programs is used in combination with other data, it is necessary to highlight a few features of the EDF data and explain how we merge the catch share data to the rest of the data.

A few countries have different regulations for different segments of their fishing fleet. The UK, for example, distinguishes between their inshore fleet and the rest of the fleet. The inshore fleet includes vessels which are less than 10m long and fish close to the coast. This fleet segment is subject to different quota regulations than the rest of the fishing fleet. Similarly, Australian regulations can differ based on the gear type used to catch a particular species. Other countries distinguish between different fishing regions and introduce catch share programs for different regions at different times. These different regulations are recorded in the EDF dataset and hence the EDF data are not only country-species-specific but also fleet-specific. There are a few instances in which catch share programs for a particular species are introduced in different years for different fleet segments.

Since the remainder of our data is at the country-species level and does not distinguish between different fleet segments, we record a particular species as managed as soon as a country adopts a catch share program for one particular segment of its fleet which targets the respective species.

This assumption is unlikely to have a large impact on the results since the problem is not very prevalent. For 709 managed fisheries at the country-species level the dataset only records one catch share program per country and species. For 66 country-species observations, there are two programs targeting the same species within a country and in 24 cases there are more that two programs which regulate the catch of a particular species within one country.

For the purpose of the analysis, it is important to know when the catch share program was adopted. Information on the year of adoption is missing for 146 observations in the original EDF dataset. We use information from government websites and scientific articles and contacted the respective governments to complete this information where possible. For some country-species combinations it was impossible to find out when the catch share programs were introduced. Those country-species combinations are deleted from the dataset. Table 4.2 shows the number of catch share programs for which the start year is missing by country of adoption. The start year is missing for all managed fisheries in Belgium, Finland, Germany, Latvia, Lithuania, Malta, Papua New Guinea and Poland. These countries are, thus, not in our sample. This is unlikely to introduce a sample selection issue, since this covers a large spectrum of countries.

Table 4.2: Location of catch share programs with missing start year

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

4.4.2 Landings

The management data are matched with data on landings and prices from Swartz et al. (2012).[16]

The level of aggregation at which the countries report their landings statistics varies. Most countries provide landings statistics at the species level. Landings statistics for a few countries, like Australia for example, are more aggregate. If a country does not provide catch statistics at the individual species level, the matching between the catch data and the management data is more complicated. This can be illustrated using an example. Aus-

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

tralia implemented catch share programs for different kinds of lanternsharks including smooth lanternshark, short tail lanternshark, pink lanternshark and others. Australian catch statistics, however, do not distinguish between these categories and only report landings of lanternsharks in general. In that case, we assume that lanternsharks are managed as soon as the Australian government introduces management for the first lanternshark species.

The matching is based on the fish species' common name. Since fish species are often know under several common names and since the data on landings can be slightly more aggregate than the management data, we construct a concordance table using information from FishBase.[17] This online database records the different common names and scientific names for more than 30 000 fish species.

4.4.3 Price data

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

4.4.4 Trade data

Even though this chapter focuses on the relationship between the price and fisheries management, Section 4.11 examines the relationship between the introduction of catch share programs and other proxies for trade openness. Disaggregate trade data for almost all countries are available from the FAO Fisheries Commodities Production and Trade Statistics for the years 1976 to 2009. The trade data are matched with the data on landings and management at the species level. There is no existing concordance table for the landings statistics and the trade statistics. Hence, this table was constructed in the process of the research undertaken for this project. The next few paragraphs describe the matching in detail.

Table 4.3 provides some examples for categories in the trade data and shows two important features. Firstly, the FAO trade data provide information on the way the fish is processed. For the purpose of our analysis, it does not matter whether the fish is fresh, frozen or prepared. Therefore, we

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[17] Froese and Pauly (2015), `www.fishbase.org`

Table 4.3: Categories in the trade data

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

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

Table 4.3 also shows that exports and imports are recorded at the species level for some kind of fish like Atlantic cod and European plaice. For other species, the trade statistics are reported in more aggregate categories. This is the case for mussels. The category mussels includes a whole range of species and the landings data would generally provide information at a more disaggregate level. Since it is not possible to know which of the species in our landings data are traded and which ones are not traded, we cannot use the trade data for aggregate categories like “Mussels” for the purpose of our analysis.

Since the trade data and the landings as well as the aquaculture data are not always available at the same level of aggregation, the matching between the datasets is only possible for some of the species. However, it is possible to aggregate all of data to the level at which species are grouped in the International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP).[18] The ISSCAAP classification divides species into divisions such as Marine fish, Crustaceans and Molluscs. Each division is split up into subgroups such as "Flounders, halibuts and soles" or "Cods, hakes and haddocks". It is possible to match the trade and landings data at the level of the latter subgroups.

4.4.5 Aquaculture data

In Section 4.11 we will use a measure of trade openness which is defined as exports and imports relative to domestic production, including aquaculture

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[18] Details on the classification are available from the FAO’s website under `ftp://ftp.fao.org/FI/DOCUMENT/cwp/handbook/annex/AnnexS2listISSCAAP2000.pdf`.

production. Aquaculture data at the species level are available from FAO Fishstat J. We match them to the landings statistics at the species level using the ASCIP codes.

Both the value of aquaculture production and the trade values are deflated using the US consumer price index for meat, poultry and fish from the US Bureau of Labour Statistics. Deflation allows us to compare trade and aquaculture production to the value of landings reported in the dataset by Swartz et al. (2012), which are also deflated using the consumer price index from the US Bureau of Labour Statistics.

4.4.6 Fish population growth rates

The fish population growth rates are from the Fisheries Centre at UBC. The intrinsic population growth rate is proxied by the maximum population growth rate.[19] The data on the fish population growth rates are matched to the landings and price data based on the fish species' common name. We use information from FishBase to construct the concordance table between the common names.[20]

4.4.7 Country-level data

Data on the number of fishermen are from the FAO. Section 4.13.1.1 in the Data Appendix describes the construction of the variable in detail.

Data on GDP per capita, agricultural value added and resource rents as a percentage of GDP are from the World Development Indicators. The corruption data are from the PGR Group's International Country Risk Guide. Data on the length of the coastline are from the CIA World Factbook.

The catch and price data report separate entries for overseas territories like the Virgin Islands, the Falkland Islands, Reunion or Martinique or for regions like Alaska. However, the country level data (i.e. the FAO trade

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

[20] The landings data provide the fish species' common name as the only indicator. The data on the fish population growth rates also provide information on the taxonomic name of the fish species. In order to facilitate the matching between the price and fish population growth rates and the trade and aquaculture data, we make use of a larger range of species-specific indicators. We match the data on the price and fish population growth rates with the FAO's ASFIS list of species, which is available from `http://www.fao.org/fishery/collection/asfis/en`. This list includes the species' ASFIS codes, which are unique 3 digit species specific indicators. Moreover, the ASFIS list of species includes the ISSCAAP codes and a range of other useful indicators about the species' biological classification. The matching is based on the taxonomic name or the common name and the concordance table is constructed by the author.

data and WDI data) data do not always report separate entries for these overseas territories. We aggregate all data to the level at which the the WDI data are available. Section 4.13.1.2 in the data appendix describes this in detail.

4.5 Description of managed fisheries

This section gives an overview of the management data. We investigate which countries adopt catch share programs and explore in which years the programs were introduced. Moreover, we investigate which species are managed and the types of catch share programs which are most prevalent.

4.5.1 Which countries introduce fisheries management?

Catch share programs can be found all around the world, but they are most prevalent in Europe, North America and the Pacific. Table 4.4 shows how many catch share programs each country introduced.[21] The countries with the largest number of catch share programs are Australia, New Zealand, Chile, and the United States.

The empirical analysis in Sections 4.7 and 4.8 is based on a subsample of the countries which introduce fisheries management. This is due to limited data coverage for the control variables in the analysis. The asterisks in Table 4.4 mark the countries which are in the dataset used for the empirical analysis. Our sample includes countries from all continents and all stages of development. It contains all countries which introduce catch share programs for a broad range of species except New Zealand.

Our empirical analysis focuses on catch share programs which were introduced by governments and abstracts from regulations which are based on social norms. Customary use rights programs, such as those in the Philippines, Solomon Islands, Vanuatu and Bangladesh are not in the sample.

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[21] Note that this list is not exclusive since our dataset does not cover all catch share programs. We do not include catch share programs for freshwater fish species as well as catch share programs for which the start year is missing. Moreover, the TURF program for the Cook Islands is not included since we do not have any WDI data for this program.

Table 4.4: Catch share programs by area

	(1) Freq
East Asia & Pacific	
Australia*	55
Cook Islands	1
Fiji	5
Japan	12
New Zealand	91
Philippines	1
Solomon Islands	6
Vanuatu	3
Total	174
South Asia	
Bangladesh	6
Total	6
Europe & Central Asia	
Denmark*	21
Estonia*	13
Iceland*	22
Italy*	8
Netherlands*	13
Norway*	8
Portugal*	19
Sweden	5
United Kingdom*	39
Total	148
Latin America & Caribbean	
Argentina*	1
Chile*	63
Mexico*	7
Peru	1
Total	72
North America	
Canada*	37
United States*	54
Total	91
Sub-Saharan Africa	
Namibia	8
South Africa*	5
Total	13

4.5.2 Which fish species are managed?

Which fish species are most likely to be managed? Table 4.5 shows the number of catch share programs per ISSCAAP group and reveals that a whole variety of fish species are managed via catch share programs. Most of the catch share programs apply to marine fish. Amongst those, cods, hakes and haddocks are the species which are managed most frequently. There is also a large number of catch share programs for demersal fish species, which live close to the seabed: 46 catch share programs manage flounders, halibuts and soles and another 59 apply to miscellaneous demersal fishes. Furthermore, there are 17 programs to manage the catch of diadromous fish species, which migrate between salt water and the freshwater. 38 programs cover crustaceans like crabs, lobsters and shrimps and another 40 programs manage molluscs, including clams, mussels, oysters, scallops and squids.

These different species inhabit different parts of the ocean. This implies that catch share programs are not confined to species which are caught close to the coast and which are particularly easy to monitor.

Catch share programs were implemented for a broad spectrum of species which are caught using different gear types. Data on the gear type is incomplete. However, the data which are available to us show that catch share programs cover the whole spectrum of gear types including trawling, gill nets, seines, hook & line, dredges, pots & traps as well as hand collection.

4.5.3 When were the catch share programs introduced?

Catch share programs have a long tradition. The earliest catch share programs which are recorded in our dataset are Territorial Use Rights for Fishing (TURF) programs in Japan. Japan had TURF programs for a range of species before 1900. Moreover, a Fiji, Papua New Guinea, the Solomon Islands and Vanuatu have customary use rights programs to guarantee the sustainability of their fisheries. Those programs fall into the category of TURF programs. The start date of these programs is unknown, but according to Jardine and Sanchirico (2012), the customary use rights programs in the Solomon Islands and Vanuatu were in place before 1950.

The earliest quota-based catch share programs were introduced by the United States and Canada in the early 1970s.

Catch share programs became popular in the 1990s. Table 4.6 displays the number of catch share programs by adoption time and type of catch share program. The last column of Table 4.6 shows that 217 out of the 504

Table 4.5: Catch share programs by group of fish species

	(1) Freq
Marine Fishes	
Cods, hakes, haddocks	66
Flounders, halibuts, soles	46
Herrings, sardines, anchovies	24
Miscellaneous coastal fishes	29
Miscellaneous demersal fishes	59
Miscellaneous pelagic fishes	30
Sharks, rays, chimaeras	20
Tunas, bonitos, billfishes	17
Total	291
Diadromous Fishes	
Miscellaneous diadromous fishes	1
Salmons, trouts, smelts	16
Total	17
Crustaceans	
Crabs, sea-spiders	8
King crabs, squat-lobsters	7
Lobsters, spiny-rock lobsters	16
Miscellaneous marine crustaceans	2
Shrimps, prawns	5
Total	38
Molluscs	
Abalones, winkles, conchs	5
Clams, cockles, arkshells	16
Mussels	5
Oysters	1
Scallops, pectens	9
Squids, cuttlefishes, octopuses	4
Total	40
Miscellanous aquatic animals	
Sea-squirts and other tunicates	1
Sea-urchins and other echinoderms	9
Total	10

programs in our dataset were implemented in the 1990s and the rate at which the programs were introduced remained high in the 2000s.[22]

Table 4.6: Type of catch share programs

	(1) Cooperative Freq	Quota Freq	TURF Freq	Total Freq
1901-1969	0	0	30	30
1970-79	0	7	1	8
1980-89	1	69	1	71
1990-99	1	147	69	217
2000-2006	6	101	3	110
2006 onwards	10	58	0	68
Total	18	382	104	504

4.5.4 Different types of catch share programs

Quota programs are by far the most prevalent type of catch share program. The last row of Table 4.6 shows that 382 out of 504 programs, or 76 percent of the catch share programs in our dataset are quota programs. 77 percent of those are Individual Transferable Quota programs. The remainder are individual vessel quotas, individual quotas and a very small number of community fishing quotas.

Another 20 percent of the fisheries are managed through Territorial Use Rights for Fishing (TURF) programs. 4 percent of the managed fisheries are managed by cooperatives and it is not clear whether the approach is based on quotas or on territorial use rights. The respective fisheries are located in the United States or in Mexico.

4.6 Summary statistics and stylized facts

This section provides summary statistics and stylized facts about the fisheries which introduce catch share programs. The stylized facts give a first idea of the factors which affect a government's decision to introduce catch share programs. The focus is on the variables which are used in our analysis. A detailed description of the characteristics of managed fisheries is available in the Stylized Facts Appendix 4.13.2.

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[22] Our sample does not include all catch share programs. Table 4.24 in the Results Appendix shows the precise year in which catch share programs in our sample were introduced.

The sample period covers the years 1984 to 2003. A few catch share programs were introduced prior to 1984. However, delayed entry is not a problem for our analysis. Only 5 percent of all catch share programs were introduced between 1900 and 1984 and almost half of those were customary use rights programs which are based on social norms. The empirical analysis in this chapter does not consider customary use rights programs.

During the sample period, 179 fisheries in our sample introduce catch share programs. Table 4.24 in the Appendix shows the number of fisheries which adopted management in every year. By 1994, 50% of the management programs in our sample were in place.

Table 4.7 provides summary statistics for all variables which are used in our analysis. This first column of Table 4.7 shows the mean of each variable for all fisheries which adopt management in the year in which they adopt management. In other words, the summary statistics in Column 1 of Table 4.7 give a snap shot of the managed fisheries at the time at which management is introduced. The second column of Table 4.7 provides summary statistics for unmanaged fisheries. This group includes both the fisheries which are unmanaged at a particular point in time but adopt management at a later point in time as well as the fisheries which are unmanaged throughout the sample period. Table 4.8 displays the results of t-tests for a difference in means between the managed and unmanaged fisheries.

Table 4.7: Summary statistics for managed and unmanaged fisheries

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

Tables 4.7 and 4.8 show that the average log of the lagged price of fish

Table 4.8: T-test for difference in means

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

t statistics in parentheses

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

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

This pattern follows through if we compare the average price for adopters of catch share programs to the average price for non-adopters for each year in the sample separately, as can be seen in Figure 4.1. The blue dots in Figure 4.1 show the average price for fisheries which adopt management in a particular year between 1984 and 2003. The average price for non-adopters is represented by the red dots. The dashed lines show the upper and lower bounds of the confidence intervals of the average price for both groups.[23] The figure confirms that there is no statistically significant difference between the price for adopters and non-adopters of catch share programs.

The description of the dataset in Section 4.4.3 explained that part of the price data are estimated. If we only use the price data which are not estimated, the average price is significantly lower for fisheries which introduce catch share programs, as demonstrated by the variable "Ln (Lagged Price), Data" in Tables 4.7 and 4.8.[24]

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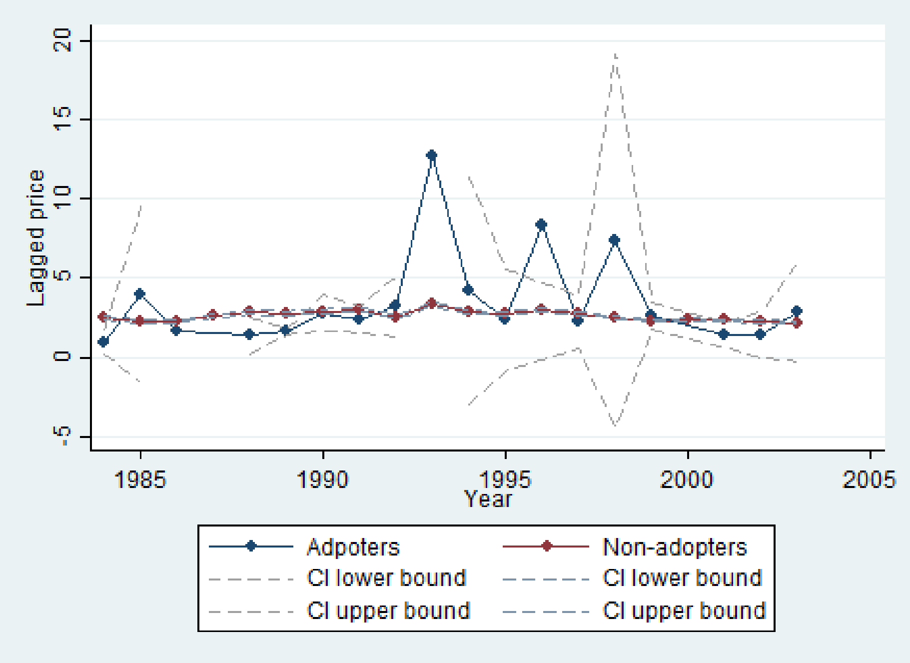
[23] Since the number of country-species-observations which adopt management in every year is small, the confidence interval for the adopters is large.

[24] The correlation Table 4.25 in the Results Appendix shows the unconditional correlation between management and all of the covariates used in the analysis. The price is not significantly correlated with the introduction of catch share programs. The table also reveals that the adoption of catch share programs is positively correlated with GDP per capita, agricultural value added and the length of the coastline. Management is

Figure 4.1: Average lagged price for adopters of catch share programs and others



The summary statistics in Table 4.7 also reveal that fisheries which adopt catch share programs are in countries with higher agricultural value added. Agricultural value added is used as a proxy for fishing technology and Section 4.13.2.6 in the Stylized Facts Appendix shows that countries which adopt catch share programs also fare better in a range of other indicators for technology such as the number of patent applications and R&D expenditure.

On the other hand, the summary statistics show that countries which introduce catch share programs have a longer coastline than unmanaged fisheries. Hence, they have access to larger fishing grounds. Moreover, catch share programs are implemented in countries with a smaller number of fishermen. The average fishery which introduces a catch share program is in a country with about 45 000 fishermen, whereas the average number of fishermen at the country-level amounts to around 354 000 people in fisheries which do not introduce catch share programs (see variable "Fishers" in Table 4.7). This implies that pressure on the fisheries which introduce catch share programs should be low, since a smaller number fishermen fish in larger fishing grounds.

Fisheries collapse is less prevalent amongst adopters of catch share programs. This would also imply that pressure on the fisheries which introduce

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significantly negatively correlated with the fish population growth rate, the number of fishermen, corruption and resource rents. Trade openness is not significantly correlated with the introduction of rights-based management.

catch share programs is lower. However, this difference between adopters and unmanaged fisheries is not statistically significant (see Table 4.8).

Moreover, catch share programs are located in countries with significantly lower corruption, indicating better governance in those countries. Fisheries which adopt catch share programs are, on average, in countries with a corruption score of -4.99 (see Table 4.7). We rescaled the variable such that a lower value indicates less corruption and -6 is the best governance score which can be attained. An average score of -4.99, thus, shows that corruption is not widespread in countries which use rights-based approaches to fisheries management. Non-adopters are in more corrupt countries with an average corruption score of -3.46. Section 4.13.2.6 in the Stylized Facts Appendix shows that the same pattern holds for other governance indicators such as regulatory quality, government efficiency and rule of law. Fisheries which adopt catch share programs are in countries with better scores for all of these governance indicators.

Resource rents as a percentage of GDP are significantly lower in fisheries which introduce catch share programs. Hence, there is no a priory evidence that endowments with other resources and experience in managing those resources leads to better fisheries management.

Table 4.9 provides information on the sources of variation in the dataset. It shows the overall standard deviation in Column 2, the standard deviation between country-species combinations in Column 3 and the standard deviation within country-species over time in Column 4.

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

4.7 Results

The results for our baseline regression, which are presented in Column 1 of Table 4.10, show that there is a statistically significant negative relationship between the price and the introduction of catch share programs. An increase in the price by one percent is associated with a reduction in the hazard rate by 0.24 percent. This suggests that valuable species are less likely to be protected using catch share programs.

Table 4.9: Summary statistics - Sources of variation

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

In order to assess the importance of the price in determining the adoption of catch share programs, we calculate the predicted change in the hazard rate as the price increases by one standard deviation. Table 4.11 shows that such an increase in the price is associated with an increase in the hazard rate by 0.2 percent. This effect is small. However, the small effect of the price on the hazard rate is not surprising if we consider that only 179 out of almost 57 000 observations in our dataset are adopters of catch share programs. With catch share programs being this rare, the estimated effect of any regressor on the hazard rate is bound to be low.

Our study cannot explain the mechanism which leads to a negative relationship between the price and the introduction of catch share programs. Potential explanations for this result include lobbying against the introduction of catch share programs for higher-price species and cost differences. However, we defer a detailed interpretation of the negative coefficient estimate for the price variable to Section 4.9.

Moreover, the results indicate that, given survival up to time $t-1$, fisheries are more likely to be managed in time t if they are in technologically advanced countries. The coefficient estimate for the variable "Agri VA" suggests that an increase in agricultural value added per worker by 1000 constant US$ is associated with an increase in the hazard rate by 0.03 percentage points. Table 4.11 reveals that an increase in agricultural value added by one standard deviation is associated with an increase in the hazard rate by 0.37 percent.

A larger number of fishermen is estimated to have a statistically significant

Table 4.10: Baseline results

	(1) Baseline	(2) Country	(3) Species	(4) CS
Managed				
Ln (Lagged price)	−0.204***	−0.152**	−0.166**	−0.209***
	(0.069)	(0.073)	(0.080)	(0.075)
Growth	−0.187	−0.037	−0.219	−0.205
	(0.156)	(0.148)	(0.184)	(0.167)
Fishers	−0.004***	−0.002	−0.004***	−0.004***
	(0.001)	(0.004)	(0.001)	(0.001)
GDP p.c.	−0.015	0.106***	−0.028**	−0.019
	(0.011)	(0.038)	(0.012)	(0.013)
Agri VA	0.030***	−0.019	0.038***	0.035***
	(0.009)	(0.024)	(0.010)	(0.011)
Corruption	−0.732***	−0.894***	−0.717***	−0.803***
	(0.122)	(0.238)	(0.123)	(0.137)
Coastline	0.025*	0.225	0.028*	0.035*
	(0.015)	(0.151)	(0.016)	(0.018)
Collapsed	−0.611***	−0.506**	−0.574**	−0.591**
	(0.224)	(0.227)	(0.230)	(0.236)
Resource rents	0.005	0.034	0.007	0.006
	(0.013)	(0.050)	(0.013)	(0.013)
Year FE	Yes	Yes	Yes	Yes
Country RE	No	Yes	No	No
Species RE	No	No	Yes	No
Country-Species RE	No	No	No	No
N	56816.000	56816.000	56816.000	56816.000

Standard errors in parentheses

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

Table 4.11: Predicted change hazard rate

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

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

negative effect on the adoption of catch share programs. The coefficient estimate for the variable "Fishers" in Table 4.10 indicates that an increases in the number of fishermen by 1000 reduces the hazard rate by 0.004 percent. Table 4.11 shows that the variation in the number of fishermen can explain more of the variation in the hazard rate than any of the other variables. An increase in the number of fishermen by one standard deviation is associated with a reduction in the hazard rate by almost 5 percent.

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

Moreover, fisheries in countries with a longer coastline are more likely to be managed. As the coastline increases by 1000 km, the hazard rate is predicted to increase by 0.025 percent. A longer coastline implies that a country has access to larger fishing grounds. Hence, this result suggest that access to fishing grounds could make management more likely. However, variation in the length of the coastline cannot explain much of the variation in the adoption of catch share programs. An increase in the coastline by one standard deviation is predicted to raise the hazard rate by merely 0.07 percent (see Table 4.11). This small effect of the coastline on the hazard rate could be due to the fact that the access to fishing grounds does not inform us about the availability of fish in the country's coastal area.

The finding that catch share programs are more likely in countries with a longer coastline and particularly in countries with less fishermen suggests that lower capacity in the fishing industry is favourable for the adoption of resource management. The positive coefficient estimate for the dummy variable "Collapsed", which indicates fisheries collapse, is in line with that interpretation. Governments are 0.73 percent less likely to introduce catch share programs in collapsed fisheries, given survival up to time $t-1$. This finding is surprising, considering the anecdotal evidence that poster child adopters of catch share programs like Canada and Iceland introduced catch share programs as a reaction to overfishing and declining fish stocks (see Parsons, 2010; Matthiasson and Agnarson, 2010). Yet, it is important to bear in mind, that fisheries collapse has become very prevalent over the course of our sample period. The stylized facts in Section 4.13.2.5 show that 21 percent of the unmanaged fisheries in our sample have collapsed by 2003. Fisheries collapse is less prevalent amongst the adopters of catch share programs. Despite the fact that catch share programs are often introduced in response to overfishing, governments in countries which embrace these rights-based management tools seem more likely to react before a serious crisis hits the fishery. This hints towards better governance in countries which introduce catch share programs.

The results support this idea. Governance is proxied through the variable "Corruption". The statistically significant negative coefficient estimate for this variable indicates that corruption hinders the adoption of catch share programs. Corruption is measured on a point scale with 6 points. An increase in the corruption indicator by one point is associated with a reduction in the hazard rate by 0.73 percent. Table 4.11 suggests that corruption is the second most important determinant for the adoption of catch share programs. An increase in the corruption indicator by one standard deviation is associated with a reduction in the hazard rate by 1 percent. This finding is in line with anecdotal evidence, which suggests that weak governance and corruption are important obstacles to sustainable fisheries management (see e.g. Williams and Staples, 2010; Satia and Jallow, 2010; Nandakumar and Nayak, 2010).[25]

There is no statistically significant relationship between resource rents

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[25] 148 out of the 179 fisheries in our sample are in OECD countries which are considered to have relatively good governance. The results follow through if we restrict the sample to OECD countries, indicating that even amongst the OECD countries, those with better governance are more likely to introduce catch share programs.

as a percentage of GDP and the introduction of fisheries management. Resource abundance does not seem to generate any spillovers which would lead to better or worse management of a renewable resource like fisheries.

Moreover, the fish population growth rate and GDP per capita are not significantly related to the adoption of catch share programs. The stylized facts in Section 4.13.2.8 reveal that fisheries which introduce catch share programs are located in countries with higher GDP per capita. However, the correlation table 4.25 in the Results Appendix shows that GDP per capita is highly correlated with the agricultural value added per worker and corruption. It is, thus, possible that GDP per capita does not affect management once we have controlled for those two variables.

4.8 Sensitivity analysis

4.8.1 Mixed models

The results presented in our baseline regression exploit variation across country-species combinations as well as variation within country-species combinations across time. Our baseline model does not control for individual heterogeneity. This section explores whether controlling for country-specific, species-specific or country-species-specific heterogeneity changes the results. The discussion focuses on the relationship between the price and the introduction of catch share programs.

First, we look at country-species-specific heterogeneity. We allow for country-species specific effects v which scale the hazard rate in the following way:

$$\theta(t, X, v) = v\theta(t, X) \tag{4.4}$$

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

The results for a regression which allows for country-species-specific heterogeneity are displayed in Column 4 of Table 4.10. The significance pattern and the magnitude of the coefficient estimates are very similar to the results in Column 1 of Table 4.10. A likelihood ratio test comparing the baseline model and the model with frailty allows us to conclude that individual heterogeneity is not important in the context of our analysis. Therefore, we will focus on models without country-species-specific heterogeneity for the remainder of this chapter.

Even though there is no evidence that country-species-specific factors affect our results, it may still be useful to control for unobserved and time invariant country- or species-specific heterogeneity.

If we assume that the unobserved country- or species-characteristics are uncorrelated with the regressors, we can use a mixed-effects model with country- or species-specific intercepts. It is possible to model several levels of random effects in mixed models as long as the effects are nested. Since species and countries are not nested in our dataset, we can only use one type of random effect at a time.

The results for a model with country-level random intercepts are displayed in Column 2 of Table 4.10. Generally, it is not possible to compare the magnitude of coefficient estimates across nonlinear models which include different types of unobserved heterogeneity. However, we can compare the sign and significance pattern of the coefficient estimates in Column 2 to the results of the model without country-specific heterogeneity in Column 1 of Table 4.10. In both models, the hazard rate declines in the log of the lagged price of fish. Moreover, management is less likely for collapsed fisheries and fisheries in corrupt countries.

Column 3 of Table 4.10 shows the results for a model with species-specific random intercepts. The sign and significance pattern is very similar to the results of the baseline model presented in Column 1.

4.8.2 Fixed effects in nonlinear panel models

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

Unfortunately, the nice properties of fixed effects estimators in linear panel data models do not translate to nonlinear models. The joint estimation of a large number of fixed effects and the slope parameters β can lead to inconsistent estimates in nonlinear models. Due to the large number of species and country-species combinations, the use of country-species fixed effects or species fixed effects is not viable.[26]

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

It is possible to use a model with country fixed effects. There are only 15 countries which adopt catch share programs in our sample. This means that the number of country dummy variables is small and unlikely to lead to inconsistent estimates, especially since the number of observations per country is large. The use of country dummy variables implies that the sample only contains observations from countries which adopt catch share programs at some point during the sample period. The observations from countries which do not introduce catch share programs at any point cannot be used since the country dummy variables perfectly predict the (non-)adoption of the catch share programs.

Since the use of country-fixed effects reduces the sample size, any change in the coefficient estimates could either be due to the smaller sample or due to the country fixed effects. In order to be able to distinguish between these two factors, we repeat the baseline regression for the smaller sample. The results are displayed in Column 1 of Table 4.12. They show the same pattern as the results in the baseline regression.

Results for a regression using country fixed effects are presented in Column 2 of Table 4.12. The results corroborate the finding that the price, fisheries collapse and corruption are significantly negatively correlated with the introduction of catch share programs.

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

4.8.3 Fixed effects in a linear probability model

Due to the complication of estimating fixed effects in a nonlinear panel model, we use a linear probability model with fixed effects as a robustness check. The structure of the dataset is unchanged and the observations are deleted from the dataset once management has been adopted. Hence, the dependent variable is the hazard rate, or the probability of introducing management in year t, conditional on the fishery being unmanaged in year $t-1$.[27]

The regression results are presented in Table 4.13. The first column of

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is complicated due to the difficulties in calculating the marginal effects. The marginal effects are a function of the fixed effect and can thus only be calculated based on certain assumptions concerning these fixed effects.

[27] Due to the heteroskedasticity in linear probability models (Wooldridge, 2010, p. 562), we use cluster-robust standard errors.

Table 4.12: Cloglog model - Country FE

	(1) None	(2) Country
Managed		
Ln (Lagged price)	-0.190^{***}	-0.140^{*}
	(0.069)	(0.073)
Growth	-0.070	-0.020
	(0.146)	(0.147)
Fishers	-0.004^{***}	$0.034**$
	(0.001)	(0.015)
GDP p.c.	-0.049^{***}	0.079
	(0.011)	(0.063)
Agri VA	0.047^{***}	-0.003
	(0.009)	(0.026)
Corruption	-0.490^{***}	-1.129^{***}
	(0.139)	(0.286)
Coastline	-0.018	
	(0.015)	
Collapsed	$-0.579**$	$-0.492**$
	(0.225)	(0.226)
Resource rents	0.092^{***}	0.120
	(0.025)	(0.081)
N	18914.000	16021.000

Standard errors in parentheses

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

Table 4.13 shows the results for a linear probability model without fixed effects. Those results can be used as a benchmark. Just as in the non-linear model, the results suggest a negative relationship between the price and the likelihood of introducing a catch share program. However, the estimated effect of the price on management is small. An increase in the price by one US$ per kilo is estimated to make the introduction of a catch share program 0.00013 percent less likely.

When country-fixed effects are added to the model, the relationship between the price and the probability of introducing catch share programs is negative but not statistically significant (see Column 2 of Table 4.13). This result differs from our findings in the nonlinear model, which suggested a negative relationship between the price and management even after controlling for country fixed effects. However, this difference may not only be due to a poor fit of the linear probability model but also due to differences in the sample size. In the nonlinear model with country-fixed effects, the sample only included observations of countries which adopt catch share programs during the sample period.

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

The results for a linear probability model with species-fixed effects are shown in Column 3 of Table 4.13. The results confirm a negative, albeit statistically insignificant relationship between the price and the introduction of catch share programs. The coefficient estimate for the price variable is slightly smaller, in absolute terms, than in the regression without species fixed effects in Column 1 of Table 4.13. There are two possible explanations for that: Firstly, it is possible that time-invariant species characteristics are correlated with the price variable and that the coefficient estimate for the price variable is biased downward in the model without species-fixed effects. Secondly, the coefficient estimates could differ across the two models since they exploit different types of variation. The model without fixed effects exploits variation across species and suggests that lower-priced species are less likely to be managed. The fixed effects model only exploits variation within species across time and across countries and suggests that an increase in the price of a species over time or across countries does not affect the decision to introduce a catch share program.

Country-species-pair fixed effects are more suitable to analyse the effect of variation in the price within countries across time on the adoption of catch share programs. The results for such a model are presented in Column 4 of Table 4.13. Those results suggest that an increase in the price of a particular species by one percent raises the probability of introducing catch limits by 0.00071 percent. The effect is statistically significant but small. This results is contrary to our previous findings but it is not robust. If we restrict the sample to the price data which were not estimated, the coefficient estimate for the price variable is not statistically significant.

4.8.4 Attenuation bias?

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

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

The results for a regression using the small sample are displayed in Table 4.14. The negative coefficient estimate for the price variable is larger, in absolute terms, than in the baseline regression in Table 4.10 and statistically significant.

Note that we can only compare the coefficient estimates for the two regressions if we assume that both are random samples of the same population. In order to investigate whether the sample in which the price data were not estimated is representative, we compare the observations for which we have price data to the observations for which the price data are estimated. Table 4.15 provides summary statistics for both groups. Column 1 shows the means for the variables of interest to our analysis for all observations for which price data are available. Column 2 displays the mean for the observations for which the price data were estimated. The table reveals substantial differences in the means between the two groups. The t-test in

Table 4.13: Linear probability model with fixed effects

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

Standard errors in parentheses

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

Table 4.14: Attenuation bias and reverse causality

	(1) Price data	(2) Trade data	(3) Trade data
Managed			
Pr*large			0.483
			(0.337)
Pr*closed			−0.204
			(0.391)
Ln (Lagged price)	−0.483∗∗∗	−0.394∗∗∗	−0.419∗∗∗
	(0.127)	(0.121)	(0.132)
Growth	0.090	−0.466	−0.454
	(0.291)	(0.505)	(0.523)
Fishers	−0.005 ∗ ∗	−0.004	−0.003
	(0.002)	(0.003)	(0.003)
GDP p.c.	−0.153∗∗∗	−0.030	−0.030
	(0.025)	(0.020)	(0.020)
Agri VA	0.092∗∗∗	0.020	0.020
	(0.015)	(0.017)	(0.017)
Corruption	−1.292∗∗∗	−0.779∗∗∗	−0.761∗∗∗
	(0.337)	(0.246)	(0.244)
Coastline	−0.067 ∗ ∗	0.037	0.038
	(0.032)	(0.035)	(0.035)
Collapsed	−0.440	−0.488	−0.442
	(0.482)	(0.356)	(0.359)
Resource rents	0.170∗∗∗	0.033	0.030
	(0.057)	(0.035)	(0.036)
Year FE	Yes	Yes	Yes
N	5008.000	3072.000	3072.000

Standard errors in parentheses

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

Table 4.16 shows that the difference in means is statistically significant for all of the variables.

Table 4.15: Summary statistics by availability of price data

	(1) Data mean	sd	(2) Estimated mean	sd
Managed	0.01	0.10	0.00	0.05
Ln (Lagged price)	0.69	1.17	0.40	1.07
Growth	0.37	0.52	0.52	0.75
Fishers	186.25	304.20	367.96	1220.59
GDP p.c.	30.90	12.23	11.18	12.47
Agri VA	22.72	12.35	9.55	11.71
Corruption	-4.54	1.02	-3.44	1.32
Coastline	1.69	2.42	1.18	2.99
Collapsed	0.16	0.37	0.18	0.39
Resource rents	1.67	3.08	6.60	10.53
Observations	5008		50556	

Table 4.16: T-test by availability of price data

	(1)	
Managed	0.00809^{***}	(9.65)
Ln (Lagged price)	0.283^{***}	(17.73)
Growth	-0.145^{***}	(-13.39)
Fishers	-181.7^{***}	(-10.50)
GDP p.c.	19.73^{***}	(106.96)
Agri VA	13.17^{***}	(75.54)
Corruption	-1.093^{***}	(-56.85)
Coastline	0.515^{***}	(11.82)
Collapsed	-0.0245^{***}	(-4.30)
Resource rents	-4.937^{***}	(-33.03)
Observations	55564	

t statistics in parentheses

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

4.8.5 Reverse causality?

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

Sign of the bias

Identifying the sign of the bias is difficult, but it is possible in a simplified case without control variables. In the absence of fisheries management, the price is determined by supply and demand. The introduction of a quota effectively reduces supply to the quantity Q_{quota}. In that case, the price is determined by the intersection of a demand curve and a vertical line which determines Q_{quota}.

Q_{quota} is set by the government and it is a function of the price. The government's decision to regulate the fishery yields the first (and simplified) behavioural equation of the simultaneous equations model:

$$Q = \alpha_1 P + u_1 \tag{4.5}$$

The demand curve represents the second behavioural equation:

$$P = \alpha_2 Q + u_2 \tag{4.6}$$

With the usual downward-sloping demand curve α_2 is negative.

We solve these two equations for the price as a function of the exogenous variables in the model. This yields

$$P = \frac{\alpha_2 u_1 + u_2}{1 - \alpha_2 \alpha_1} \tag{4.7}$$

Estimation of Equation 4.5 is biased if the price variable is correlated with u_1 or, in other words, if $\frac{\alpha 2}{1-\alpha_2\alpha_1} \neq 0$. The sign of the bias is[28]

$$Cov(P, u_1) = \frac{\alpha_2}{1 - \alpha_2 \alpha_1} E(u_1)^2. \tag{4.8}$$

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[28] See e.g. Wooldridge (2009).

If an increase in the price facilitates resource management, as suggested by Demsetz (1967); Copeland and Taylor (2009); Hotte et al. (2000) and Tajibaeva (2012), then $\alpha_1 > 0$. With $\alpha_2 < 0$, $Cov(P, u_1) < 0$. This means that the coefficient estimate of the price variable could be biased downwards if the decision to introduce management and the price variable are determined simultaneously. If the bias is strong, we could observe a negative empirical relationship between the price and the introduction of catch share programs, even though the true relationship is positive.[29] Therefore, potential reverse causality in our coefficient estimates deserves further scrutiny.

Addressing reverse causality requires an instrumental variable for the price. Lacking this instrument, we make use of trade data in order to investigate whether reverse causality leads to a bias in our estimates. The introduction of catch share programs should only affect the price of fish in closed economies or in fisheries in which a country is a large exporter. In all other cases, the price should not be affected by management.

In order to investigate whether the relationship between the price and management differs across fisheries which are closed to trade, open to trade but small exporters and large exporters, we match trade data from FAO Fishstat J to the price data. We only use observations which can be matched at the species level. This reduces the sample size to 3072 observations.

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

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

The regression result for a model including these interaction terms are displayed in Table 4.14. Column 1 of Table 4.14 shows the results for our baseline regression for the smaller sample for which we have trade data at

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[29] If the true relationship between the price and resource management is negative, as in Sethi and Somanathan (1996) and Barbier et al. (2005), the direction of the bias is not clear. It depends on the magnitude of $\alpha_2\alpha_1$.

the species level.

Column 2 of Table 4.14 shows the results for the regression using the interaction terms. As in Column 1, we find a negative and statistically significant relationship between the price and management. The coefficient estimate is slightly larger than in Column 1 in absolute terms.

The coefficient estimate for the interaction term of the price variable with the dummy variable which indicates that a country is a large exporter of a particular fish species "Pr*large" is statistically insignificant. The same holds for the interaction term between the price and the dummy variable for closed fisheries "Pr*closed". Hence, there is no difference in the relationship between the price and the adoption of catch share programs across small open fisheries, closed fisheries and fisheries which are large exporters. The results in this Table 4.14 suggest that the coefficient estimate for the price variable is not biased due to reverse causality.

4.8.6 Further robustness checks

Further robustness checks are presented in Section 4.13.3 in the Results Appendix. Sections 4.13.3.1 and Section 4.13.3.2 show that the results are not sensitive to changes in the specification of the baseline hazard or changes in the functional form.

In Section 4.13.3.3, we discuss whether our results are affected by a simultaneous introduction of catch share programs for several species within a country. Robustness checks include aggregation to the country level, which yields a negative but statistically insignificant relationship between the price and the introduction of catch share programs. Clustering standard errors at the country level and using the disaggregate dataset confirms the results of our baseline regression.

Correlation of standard errors within species (across countries) would warrant standard-errors which are clustered at the species level. Section 4.13.3.4 shows that the results from the baseline regression are robust to clustering at the species level.

Since the panel is relatively long, Section 4.13.3.5 splits the sample into 4 intervals of 5 years. This ensures that the results are not driven by comparisons of fisheries at the end of the sample period to fisheries at the beginning of the sample period. The results suggest either a negative or a statistically insignificant relationship between the price and fisheries management.

Section 4.13.3.6 in the results appendix analyses the sensitivity of our result to the use of different proxy variables for technology, fisheries collapse and the number of fishermen. Finally, Section 4.13.3.7 investigates whether there is evidence of an Environmental Kuzets Curve for the introduction of catch share programs.

4.9 The price and management - Discussion

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

4.9.1 Social norms

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

Experimental economics research on public goods provides evidence which is consistent with this story. The literature suggests that individuals contribute more to the public good if the marginal payoff for contributing is higher (see e.g. Isaac et al. (1984) and the survey article by Ledyard (1995)).[30]

We can think about fisheries in a similar way in which we think about public goods.[31] As the price of fish increases, the marginal payoff from

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

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

fishing increases. The individual incentive to refrain from overfishing and leave the resource in the pool declines, since the marginal rate of substation between the private and the public good declines. If results from public good experiments can be translated to fisheries, an increase in the price of fish fosters overfishing and the collapse of harvesting restrictions based on social norms.

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

4.9.2 Rent-seeking

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

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

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

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

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

In a rent-seeking model, a higher price should hamper the introduction of catch share programs, particularly in corrupt countries. In order to test this hypothesis in our data, we interact the log of the lagged price with the corruption indicator. The results in Column 1 Table 4.17 suggests that an increase in the price facilitates resource management in corrupt countries. This finding is at odds with lobbying as underlying mechanism.

4.9.3 Rents and fishing cost

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

Our analysis does not control for the cost of fishing due to a lack of data.[32] This lack of information on the cost side is not problematic, if rents are dissipated prior to the introduction of catch share programs. In that case, the marginal cost would be equal to the price.

However, if rents are not dissipated, it is possible that lower-priced species generate higher rents than expensive species due to lower costs.

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

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

Table 4.17: Corrutpion, overcapacity, weight, value

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

Standard errors in parentheses

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

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

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

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

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

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

According to the model, a fishery should be able to introduce resource management as the price increases if overcapacity and corruption are low. We, thus, expect the coefficient estimates for both variables to be negative.

The results are shown in Column 2 of Table 4.17. The direct effect of the price on the introduction of catch share programs is positive. A higher price is even more likely to foster the introduction of catch share programs in corrupt countries, as shown by the positive coefficient estimate for the interaction term "P*Corruption". Since less corruption is used as a proxy for more enforcement power, this finding contradicts Copeland and Taylor (2009)'s model, which predicts that an increase in the price leads to the introduction of fishing limits when enforcement power is high. However, we cannot reject Copeland and Taylor (2009)'s model based on the positive coefficient estimate for the interaction term "P*Corruption", since the country-level variable "Corruption" may not be able to capture variations in enforcement power at the species level.

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

We tested the sensitivity of our results to the measure of overcapacity using both stricter and more lenient definitions of overcapacity. The results are not sensitive to these changes. Moreover, we estimated separate regressions, each including only one interaction term between the price and corruption or between the price and one of the variables which determine overcapacity. The results for those regressions are available in Section 4.13.3.8. The coefficient estimates for the interaction terms are not statistically significant or do not have the same sign as predicted by Copeland and Taylor (2009).

4.10 Landed weight and value

In their survey of catch share programs in developing countries, Jardine and Sanchirico (2012) point out that several low-priced species which introduce catch share programs are forage fish which are caught in large quantities. The total value of landings in these fisheries is, thus, likely to be high, despite the low price. The stylized facts in Section 4.13.2.1 in the Appendix confirm this hypothesis for our dataset. Both the landed weight as well as the total value of landings in fisheries which introduce catch share programs are significantly higher than in unmanaged fisheries. This section shows that this pattern follows through once we condition on other characteristics of the fishery.

Information on the landed weight and the value of landings is from Swartz et al. (2012). The landed weight is measured in million tonnes and the value of the catch is measured in billions of constant US$. We use the lag of the respective variables as regressors in order to avoid reverse causality.

The results in Column 3 of Table 4.17 show that the landed weight is significantly positively correlated with the introduction of catch share programs and Column 4 of Table 4.17 reveals that more valuable fisheries are more likely to be managed. An increase in the value of landings by 1 billion US$ is estimated to raise the hazard rate by 0.8 percent. The effect is small, especially considering the fact that the average value of landings is 20 million US$. An increase in the value of the catch by one standard deviation is associated with an increase in the hazard rate by merely 0.1.[33]

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

4.11 Other measures for trade openness

The theoretical literature on trade in renewable resources models trade openness through an exogenous increase in the relative price of the resource. Therefore, the price has been a key variable in the analysis. Yet, changes in the price are not necessarily the result of reduced trade barriers. They can be cause by other factors which affect supply and demand.[34]

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[33] Part of the data on the value of the catch are calculated based on the estimated price data. Hence, they may be measured with error. However, the same results follow through if we use the subsample for the data for which the price data were not estimated.

[34] As long as the economy is neither closed to trade or a larger exporter, fluctuations in global demand or supply should lead to exogenous variation in the price. Therefore,

Due to the limitations of the price variable as a measure for trade liberalization, this section explores the relationship between the introduction of catch share programs and a range of other indicators for trade openness. We draw on trade data at the species level which are available from the FAO's FishStat J. The matching is described in detail in Section 4.4.4.

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

$$\text{Openness}_{ijt} = \frac{\text{Export value}_{ijt} + \text{Import value}_{ijt}}{\text{Catch (value)}_{ijt} + \text{Aquaculture (value)}_{ijt}} \tag{4.9}$$

Not all species are suitable for aquaculture production. Hence, we assume that aquaculture production is zero if FishStat J does not report aquaculture production of a particular species.

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

The regression results in Column 1 of Table 4.18 suggest that trade openness at the species level is not a significant determinant of the adoption of catch share programs. The coefficient estimate for the variable "L.Open" is negative but statistically insignificant.[35]

In this regression, the introduction of catch share programs is only significantly correlated with corruption and GDP per capita. The coefficient estimates for all other variables are not significantly different from zero. This may be due to the small sample. There are only 3127 observations in the sample and only 53 adoptions of catch share programs.

The behaviour of exporters is of particular relevance. Exporting increases the pressure on the resource. Hence, it is worthwhile investigating whether exporting as such affects the introduction of catch share programs. We use a dummy variable which takes the value of one if a country i is a net exporter of fish species j in year $t-1$ and regress this variable on the introduction of catch share programs in year t. The coefficient estimate for the variable "L.Net exporter" in Column 3 of Table 4.18 suggests that there is no statistically significant relationship between being a net exporter of species j and introducing a catch share program for species j.[36]

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an analysis of the relationship between the price and fisheries management tests the theoretical predictions, even though changes in the price do not necessarily reflect increases access to foreign markets.

[35] A thorough comparison of trade patterns for adopters of catch share programs and unmanaged fisheries is available in Section 4.13.2.2 in the Stylized Facts Appendix.

[36] The results are similar if the dummy variable takes a value of one if a country is an

Table 4.18: Trade

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

Standard errors in parentheses
* p<0.1, ** p<0.05, *** p<0.01

Moreover, we explore whether fisheries which export a larger fraction of their catch are more or less likely to introduce catch share programs. We use the lag of exports relative to domestic production as a regressor instead of the measure of openness. The results are displayed in Column 2 of Table 4.18. They show that the introduction of catch share programs is not significantly related to the percentage of domestic production which is exported. The variable "L.Export/Production" is not statistically significant. Hence, there is little evidence to suggest that exporting a larger fraction of domestic catch affects the decision to adopt a catch share program.

However, the data show that species which generate larger export earnings are more likely to be managed. We use the lag of the export value, measured in millions of constant 2005 US$ as a regressor. The results in Column 4 of Table 4.18 show that an increase in the export value by 1 million US$ in period $t-1$ raises the likelihood that a government introduces a catch share program in period t by 0.001 percent, given survival up to period $t-1$. With a standard deviation of 75, an increase in the net export value by one standard deviation is associated with an increase in the hazard rate by 0.11 percent.

The results are similar if we use the *net* export value rather than the export value. The net export value is defined as the export value minus the import value. An increase in the lagged net export value by one million US$ is estimated to raise the likelihood of introducing a catch share program by 0.002 percent. This is obvious from the coefficient estimate for the variable "L.Net exports" in Column 5 of Table 4.18. Since the standard deviation of the net export value is 99.3, the hazard rate is predicted to increase by 0.18 percent as the net export value increases by one standard deviation.[37]

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

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exporter rather than a net exporter.

[37] The lag of the import value is not a statistically significant determinant of the decision to introduce a catch share program.

According to the results which were presented in this section, trade affects fisheries management only in one way. It creates an export market on which the landings can be sold. This increases the value of the fishery. The fact that the introduction of catch share programs is higher for species with a larger export value is in line with the finding in Section 4.10, which suggested that more valuable fisheries are more likely to be managed. Part of this value seems to be created via exports.

4.11.1 Aggregation to the ISSCAAP level

Trade data at the species level are only available for a subset of our sample. Table 4.32 in the Results Appendix 4.13.3 shows the average characteristics of fisheries for which we have trade data at the species level and for fisheries for which these data are not available. The t-test of a difference in means between the two groups in Table 4.33 in the results appendix 4.13.3 reveals statistically significant differences in all average characteristics. This implies that the observations for which trade data are available at the species level are not representative of the entire sample. Hence, we cannot conclude that the relationships presented in the previous section apply to the entire population.

In order to avoid sample selection issues, we aggregate the data to the level of the ISSCAAP groups. At this level of aggregation, it is possible to match all of the trade data with the rest of the dataset and use the full sample.

The variable of interest in the aggregate regression is the percentage of managed fisheries "Perc. Man_{kit}". This variable is defined as the number of managed fisheries in ISSCAAP group k in country i in year t relative to the total number of fish species which are landed in ISSCAAP group k in country j in year t.

The percentage of managed fisheries is 0 for more than 90 percent of the observations in the aggregate dataset. This implies that left-censoring is a serious problem. This problem could be address through the use of a Tobit model. However, a Tobit model assumes that the decision to adopt catch share programs for one species and the decision about the percentage of managed fisheries are driven by the same process. Since this assumption is quite restrictive, we use a two-part model which allows for the possibility that zeros and positives are generated by different mechanisms.

In the first step, we use a complementary log log model to investigate whether any of the fisheries in ISSCAAP group k in country j in year t

uses catch shares. The dependent variable "ManI$_{ijk}$" is a dummy variable which takes the value of one if country j introduces a catch share program for any species within ISSCAAP group k in year t. Once management was introduced in year t, the observation disappears from the dataset in year $t+1$. Hence, the dependent variable has to be interpreted as the hazard rate, or the probability of introducing management in period t given that no catch share programs was introduced in period $t-1$ for any of the species in ISSCAAP group k. The approach is the same as the survival analysis in the baseline model.

The species-level control variables have to be aggregated to the ISSCAAP level. The aggregate measure for openness is defined as the sum of the export value and import value for all species j within ISSCAAP group k in country i at time t divided by the sum of the landed value and the value of aquaculture production for all species j in ISSCAAP group k in country i at time t:

$$\text{Openness}_{kjt} = \frac{\sum_{j\in kjt} \text{Export value}_{ijt} + \sum_{j\in kjt} \text{Import value}_{ijt}}{\sum_{j\in kjt} \text{Catch (value)}_{ijt} + \sum_{j\in kjt} \text{Aquaculture (value)}_{ijt}} \tag{4.10}$$

We use the lagged measure of trade openness in order to avoid reverse causality.

The percentage of collapsed fisheries, "Perc. Collapsed$_{jkt}$", is the counterpart of the variable "Collapsed" in the species-level regression. "Perc. Collapsed$_{jkt}$" is the sum of all collapsed species in ISSCAAP group k in country j in year t divided by the total number of fish species which are landed in ISSCAAP group k in country j in year t.

Moreover, the fish population growth rate is aggregated using the average of all fish population growth rates within the ISSCAAP group.

The results for the regression at the ISSCAAP level are displayed in Table 4.19. The first column of Table 4.19 shows the results for the first step regression. The dependent variable in this regression is a dummy variable which takes the value of one as soon as the government of country j has introduced the first catch share program for a fishery in ISSCAAP group k. According to the results in Column 1 of Table 4.19, openness to international trade in ISSCAAP group k does not have a statistically significant effect on the adoption of catch share programs. The corruption indicator is the only variable which is significantly correlated with management and the results confirm our previous finding that corruption hampers the introduction of catch share programs.

In the second step, we look at ISSCAAP groups in which at least one fishery is managed via a catch share program. We use an OLS regression to investigate the relationship between our regressors and the percentage of managed fisheries in each ISSCAAP category. The dataset includes observations from all ISSCAAP groups from the point in time in which the government introduces the first catch share program in the respective ISSCAAP category until the end of the sample period.

The results are displayed in Column 2 of Table 4.19. They confirm the statistically insignificant relationship between trade openness and the introduction of catch share programs.

Since we observe all ISSCAAP groups until the end of the sample period even though governments may have introduced catch share programs for some species in the ISSCAAP group, the results from this regression have to be interpreted with a grain of salt. The introduction of the first catch share program could lead to longer term adjustments in the fishery which affect the regressors. A catch share program for species i in ISSCAAP group k, e.g., could affect both the catch of species i as well as exports and imports of species i. Hence, the results may be biased due to reverse causality. However, the direction of the bias is not obvious. Exports and imports relative to domestic landings of species j could increase or decline.

In a similar vein, the introduction of a catch share program for species j should reduce the likelihood of fisheries collapse (see Costello et al., 2008) in the long run. Hence, the percentage of collapsed fisheries should be lower once a catch share program has been introduced for the first species. Due to those issues with reverse causality, the results in Column 2 of Table 4.19 have to be interpreted with caution.

Instead of using the percentage of managed fisheries as a dependent variable, we can weight each fishery by the value of the catch and use the percentage of the landed value which comes from managed fisheries as the dependent variable. The variable is defined as

$$\text{Value man}_{kjt} = \frac{\sum_{j\in kjt} \text{Catch (value)}_{ijt} * I}{\sum_{j\in kjt} \text{Catch (value)}_{ijt}} \tag{4.11}$$

where I takes the value of 1 if the fishery is managed and the value of zero if the fishery is not managed.

The results for a regression with "Value man" as dependent variable are displayed in Column 3 of Table 4.19. They suggest a negative relationship between openness to international trade and the adoption of catch share

Table 4.19: Regressions at ISSCAAP level

	(1) Cloglog	(2) Perc man	(3) Value man
Open Agg. (Lag)	-0.00000334	-0.000000753	-0.00000133**
	(0.0000168)	(0.000000542)	(0.000000665)
Fishers	-0.00113	-0.000600***	-0.000756***
	(0.00140)	(0.000121)	(0.000149)
GDP p.c.	-0.0184	-0.0112***	-0.00517***
	(0.0187)	(0.00146)	(0.00179)
Agri VA	0.0251	0.0130***	0.00965***
	(0.0189)	(0.00118)	(0.00144)
Corruption	-0.903***	0.0585***	0.0324
	(0.212)	(0.0172)	(0.0211)
Coastline	0.0329	-0.00499***	-0.00470**
	(0.0267)	(0.00170)	(0.00209)
Percentage collapsed	-0.218	-0.422***	-0.110**
	(0.506)	(0.0446)	(0.0548)
Resource rents	0.00907	0.0226***	0.0142***
	(0.0226)	(0.00329)	(0.00404)
Observations	6853	1055	1055
Managed	59		

Standard errors in parentheses

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

programs. Larger trade volumes relative to domestic production are negatively correlated with the percentage value of the catch that comes from managed fisheries.

4.12 Conclusion

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

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

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

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

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

4.13 Appendix to Chapter 4

4.13.1 Data appendix

4.13.1.1 Data on the number of fishermen

This section describes the construction of the data on the number of fishermen in detail. Information on the number of fishermen is from the FAO. FAO (1999) provides data for the years 1970 to 1997. Data for the years 1995, 2000 and 2004-2012 are available from the FAO (2014).

We use the data from table T3 in FAO (1999), which records the total number of fishermen for all countries for the years 1970, 1980 and 1990. The information on the number of fishermen for all countries with less then 500 fishers is missing in that table. In that case, we use information from Table T2 in FAO (1999). In 1990, the FAO changed its questionnaire and asked respondents to report employment in aquaculture as part of employment in the fishing industry. Consequently, total employment in the fishing industry for the year 1990 includes fish farmers. We subtract the number of fishermen in aquaculture, which is available in Table Table T2 in FAO (1999), from the total number of fishermen in 1990 to make sure that our data only represent the number of fishermen in capture fisheries.

The second data source, FAO (2014), reports the number of fishermen in capture fisheries for the years 1995, 2000 and 2004-2012. The records in FAO (2014) do not include fish farmers and are, thus, consistent with the dataset we constructed from FAO (1999).

Since the data on fishers is missing for a few years we use linear interpolation of fishermen on time to fill in the missing values. Let y denote the number of fishermen and let t denote the year. Linear interpolation uses the two closest observed data points (y_0, t_0) and (y_1, t_1) where $y_0 < y$ and $y_1 > y$ to calculate the value of y based on the following formula[38]

$$y = \frac{y_1 - y_0}{t_1 - t_0}(t - t_0) + y_0 \tag{4.12}$$

This implies that the number of fishermen develops in a linear fashion and increases or decreases by the same amount in every year between the two points in time for which we have data.

Unfortunately, FAO (2014) only reports the number of fishermen for 52 countries which catch more than 200 000 tonnes of fish in 2012. Even though

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[38] See StataCorp. (2013).

we do not have catch data for the year 2012, the catch data for the year 2006 show that most of the countries have a catch of significantly less than 200 000 tonnes. Hence, the limited data availability is likely to introduce a sample selection issue. In order to avoid this type of sample selection issue, we extrapolate the data FAO (1999) based on a linear time trend. The estimation command is the same as the one used for the interpolation described in Equation 4.12 but instead of using data for a previous year and a consecutive year, the extrapolation is based on the closest two previous records which are available in the data. In other words, we use the observed data points from 1980 and 1990 and extrapolate the time trend between these two data points into the future.

4.13.1.2 Aggregation across regions

The catch and price data report separate entries for overseas territories like the Virgin Islands, the Falkland Islands, Reunion or Martinique or for regions like Alaska. However, the country level data (i.e. the WDI data) do not always report separate entries for these overseas territories. Therefore, we aggregate the catch and price data to the country level at which the WDI data are reported. The variable catch reports that total catch in a country including the catch in the overseas territories. For the price data, we use the weighted average price in all regions in the country. The weights are based on the catch in each region. We also aggregate the trade data to the level of aggregation at which the WDI data are available. This means that exports from the UK are the sum of exports from the UK, the Falkland Islands and Montserrat.

In two instances, the catch share programs can be associated with particular regions of a country as well. This is the case for Greenland (as part of Denmark) and Alaska (part of the US). For the purpose of this analysis, Greenland will be considered an independent country since we have information on prices as well as country-level characteristics (WDI data and FAO trade data) for Greenland. Alaska will be considered a part of the US, since there are no separate trade and WDI data for Alaska. Even though the dataset reports catch data for Alaska, the coverage is very sparse and most of the species for which there are catch share programs in Alaska are not covered in Alaska's catch statistics.

Table 4.20: Summary statistics for managed and non-managed fisheries - Extended

	(1)			(2)		
	Managed			No man.		
	mean	sd	count	mean	sd	count
Coastline	3.82	6.82	179	1.23	2.92	62976
Collapsed	0.13	0.34	179	0.18	0.38	62976
Harvest						
Catch (quantity)	58725.64	196737.05	179	15847.61	137621.60	62976
Catch (value)	65201.40	173090.37	179	20159.25	128753.72	62976
Fishery percentage	0.04	0.10	179	.	.	0
Perc. man. 2006	0.57	0.32	7	.	.	0
Trade						
Export value	39294.26	100388.14	70	20416.77	73885.93	6638
Import value	14340.13	29723.10	59	28174.78	87213.88	5849
Net exports (q)	13380.46	40277.43	56	359.46	34361.73	5250
Net exports (v)	32094.48	110860.03	56	-1685.30	99976.16	5250
Exports/Production (v)	39.20	252.92	70	853.45	40554.11	6638
Exports/Production (q)	6.96	42.48	70	123.55	2117.85	6646
Openness (value)	120.19	749.88	56	1968.95	70460.50	5250
Openness (quantity)	14.54	71.31	56	410.10	5180.31	5250
World market share	0.22	0.30	69	0.17	0.30	6431
Employment						
Fishers	44.93	62.88	179	353.61	1163.65	62976
Economically active	17634.65	29007.55	179	36703.04	84446.07	62971
Fi/Active	0.01	0.01	179	0.01	0.01	62971
Technology						
GDP p.c.	25.43	12.58	179	13.19	13.80	62976
Catch per fisherman	87577.97	108494.69	173	40163.97	87895.12	62394
Agri VA	23.99	15.18	179	10.85	12.39	62976
Journals	0.03	0.04	168	0.02	0.04	59424
Patents	11.05	23.71	162	25.58	69.76	49208
Trademarks	31333.95	34240.24	164	43746.39	55391.87	52391
R&D expenditure	1.80	0.55	69	1.27	0.92	19344
R&D researchers	3139.73	1097.40	68	2185.96	1587.43	16533
Technicians	703.89	420.50	17	435.87	353.59	9770
Regulatory Quality						
Regulatory Quality	1.50	0.26	24	0.43	0.91	18201
Gov. Efficiency	1.65	0.46	24	0.51	1.02	18201
Rule of law	1.60	0.43	24	0.33	1.03	18201
Corruption WGI	1.83	0.58	24	0.43	1.09	18201
Corruption	-4.99	0.92	179	-3.55	1.34	62976
Resources						
Resource rents	3.23	3.37	179	6.17	10.33	62976
Observations	179			62976		

Table 4.21: T-test for difference in means - Extended

	(1)	
Coastline	-2.593***	(-11.79)
Collapsed	0.0522	(1.81)
Harvest		
Catch (quantity)	-42878.0***	(-4.16)
Catch (value)	-45042.1***	(-4.67)
Trade		
Export value	-18877.5*	(-2.12)
Import value	13834.7	(1.22)
Net exports (quantity)	-13021.0**	(-2.82)
Net exports (value)	-33779.8*	(-2.51)
Exports/Production (value)	814.2	(0.17)
Exports/Production (quantity)	116.6	(0.46)
Openness (value)	1848.8	(0.20)
Openness (quantity)	395.6	(0.57)
World market share	-0.0462	(-1.28)
Employment		
Fishers	308.7***	(3.55)
Economically active	19068.4**	(3.02)
Fi/Active	-0.00104	(-1.43)
Technology		
GDP p.c.	-12.24***	(-11.85)
Catch per fisherman	-47414.0***	(-7.08)
Agri VA	-13.15***	(-14.17)
Journals	-0.00831*	(-2.51)
Patents	14.54**	(2.65)
Trademarks	12412.4**	(2.87)
R&D expenditure	-0.527***	(-4.77)
R&D researchers	-953.8***	(-4.95)
Technicians	-268.0**	(-3.12)
Regulatory Quality		
Regulatory Quality	-1.064***	(-5.72)
Gov. Efficiency	-1.140***	(-5.46)
Rule of law	-1.269***	(-6.02)
Corruption WGI	-1.396***	(-6.25)
Corruption	1.436***	(14.32)
Resources		
Resource rents	2.944***	(3.81)
Observations	63155	

t statistics in parentheses

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

4.13.2 Stylized facts

This section shows stylized facts for the fisheries in our sample which adopt management. Those stylized facts should give us a first idea of the factors which affect governments' decision to introduce catch share programs. We focus on the importance of fisheries which adopt catch share programs for a country's fishing industry, on trade patterns and on a range of country characteristics. These include technology, governance indicators and resource abundance.

Table 4.20 provides summary statistics for all variables of interest. The first column of Table 4.20 shows the mean of each variable for all fisheries which adopt management in the year in which they adopt management. In other words, the summary statistics in Column 1 of Table 4.20 take a snap shot of the managed fisheries at the time at which management is introduced. Once the fisheries have adopted management, they are deleted from the dataset. This approach allows us to focus on the determinants of management and guarantees that the stylized facts are not influenced by long-run adjustments in managed fisheries. It is consistent with the survival analysis approach undertaken in the main text.

The second column of Table 4.20 provides summary statistics for unmanaged fisheries. This group includes both the fisheries which are unmanaged at a particular point in time but adopt management at a later point in time as well as the fisheries which are unmanaged throughout the sample period.

Not all variables are available for all countries or for all fisheries. Hence, we provide summary statistics for a subset of our sample for which the respective indicator is available. The column with the heading "count" displays the number of observations in the respective group.

Table 4.21 displays the results of t-tests for a difference in means between managed and unmanaged fisheries. Variable definitions as well as a the data source for all variables are summarzed in Tables 4.22 and 4.23.

4.13.2.1 Economic importance of managed fisheries

This section studies the importance of managed fisheries for a country's fishing industry. It looks at the value of the catch and the percentage of the domestic catch that comes from managed fisheries.

Managed fisheries have a higher catch both in terms of value and quantity. Table 4.20 shows that the average weight of landings (variable "Catch (quantity)") in unmanaged fisheries is about 16 000 tonnes whereas the

Table 4.22: Variable definition - Extended

Variable	Definition	Source	Years
Price	Price in constant 2005 US$ per kilo	Swartz et al. (2012)	1950 - 2006
Fish population growth	Fish population growth rate	Fisheries Centre (UBC)	-
Catch (Quantity)	Live weight of catch in tonnes	Fisheries Center (UBC)	1950 - 2006
Catch (Value)	Value of catch in thousands of constant US$	Fisheries Centre (UBC)	1950 - 2006
Fishery percentage	Value of the fishery relative to the total value of a country's catch in the year prior to the introduction of management	Author's calculations	-
Percentage managed	Total value of the catch from managed fisheries relative to the country's total value of the catch	Author's calculations	1950 - 2006
Collapsed	Catch is less than 10 percent of the maximum catch recorded since 1950.	Author's calculations	-
Aquaculture (Value)	Value of aquaculture harvest in thousands of 2005 US$ (deflated using the US consumer price index on meat, poultry and fish from the US Bureau of Labour Statistics)	FAO Fishstat J	1984 - 2012
Aquaculture (Quantity)	Live weight of aquaculture harvest in tonnes	FAO FishStat J	1950-2012
Export quantity	Net product weight of exports at the species level in tonnes	FAO FishStat J	1976 - 2011
Import quantity	Net product weight of imports at the species level in tonnes	FAO FishStat J	1976 - 2011
Export value	Value of exports at the species level in thousands of constant US$ (deflated using the US consumer price index on meat, poultry and fish from the US Bureau of Labour Statistics)	FAO FishStat J	1976 - 2011
Import value	Value of exports at the species level in thousands of constant US$ (deflated using the US consumer price index on meat, poultry and fish from the US Bureau of Labour Statistics)	FAO FishStat J	1976 - 2011
Net exports (quantity)	Export quantity - Import quantity	Author's calculations	1976 - 2011
Openness (quantity)	$\frac{\text{Export quantity+Import quantity}}{\text{Catch (quantity) + Aquaculture (quantity)}}$. This measure is defined at the species level.	Author's calculations	1976 - 2011
Net exports (value)	Export value - Import value	Author's calculations	1976 - 2011
Openness (value)	$\frac{\text{Export value+Import value}}{\text{Catch (value) + Aquaculture (value)}}$	Author's calculations	1976 - 2011
Coastline	Coastline in 1000 km	CIA World Factbook	-
Fishers	Number of fishermen in thousands	FAO	1970 - 2012, with gaps
Economically active	Economically active population in thousands	FAO/ILO	1980 - 2012

Table 4.23: Variable definition - Extended - Continued

Variable	Definition	Source	Years
Regulatory Quality	The index "[r]eflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development." WGI (2012)	WGI	1996 - 2012
Gov. Efficiency	The index captures "perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies." WGI (2012)	WGI	1996 - 2012
Rule of law	The index "[r]eflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence." WGI (2012)	WGI	1996 - 2012
Corruption WGI	The Control of Corruption Index "[r]eflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests." WGI (2012)	WGI	1996 - 2012
Corruption	Ranges from -6 to 0, with a higher value indicating higher corruption	ICRG	1984 - 2003
GDP p.c.	GDP per capita in thousands of constant 2005 US$	WGI	1996 - 2012
Agri VA	Agricultural value added per worker in thousands of constant 2005 US$	WDI	1980 - 2012
Catch per fisherman	Value of catch at the country level divided by the number of fishermen	Author's calculations	1970 - 2006
Journals	Scientific and technical journal articles in millions	WGI	1961 - 2009
Patents	Patent applications by residents in thousands	WDI	1960 - 2012
Trademarks	Total number of trademark applications	WDI	1960 - 2012
R&D expenditure	Research and development expenditure as percentage of GDP	WDI	1981 - 2011
R&D researchers	Researchers in R&D per million people	WDI	1981 - 2011
Technicians	Technicians in R&D per million people	WDI	1996 - 2011
Resource Rents (% of GDP)	Sum of oil, natural gas, coal, mineral and forest rents	WDI	1970 - 2012

average landed weight in managed fisheries is about 59 000 tonnes. The difference between the average value of the catch in managed and unmanaged fisheries is of a similar order of magnitude. The average value of the catch in managed fisheries is 65 million US$, whereas landings for the average unmanaged fishery are only worth 20 million US$. This suggests that the fisheries which adopt management are important for the country's fishing industry.

In order to study the importance of managed fisheries in more detail, we calculate the value of the fishery in the year prior to the introduction of management relative to the total value of a country's catch in the year prior to the introduction of management.[39] This variable is called *Fishery percentage*. On average, a fishery harvests about 4 percent of the country's value of landings in the year before the introduction of management. However, the importance of the individual fisheries varies considerably. While some fisheries are of negligible importance, Danish sandlaces, for example, represent 82 percent of the value of Danish landings in the year prior to the introduction of management.

Despite the fact that fisheries do not seem to be very important at the time at which management is introduced, a lot of countries manage a large fraction of their fisheries. 15 countries in our dataset have introduced catch share programs during the sample period. We calculate the total value of landings from managed fisheries relative to the value of a country's total catch in 2003. On average, by 2006, 44 percent of landings are from managed fisheries in countries which introduce catch share programs.

The finding that the fisheries are of small economic value when management is introduced and the finding that a large fraction of a country's catch is from managed fisheries at the end of the sample period is due to the fact that a lot of countries adopt catch share programs for a number of species. Even if each of those species only makes up for a small fraction of a country's total catch, a large number of catch share programs can explain why a large fraction of the catch is from managed fisheries at the end of the sample period.

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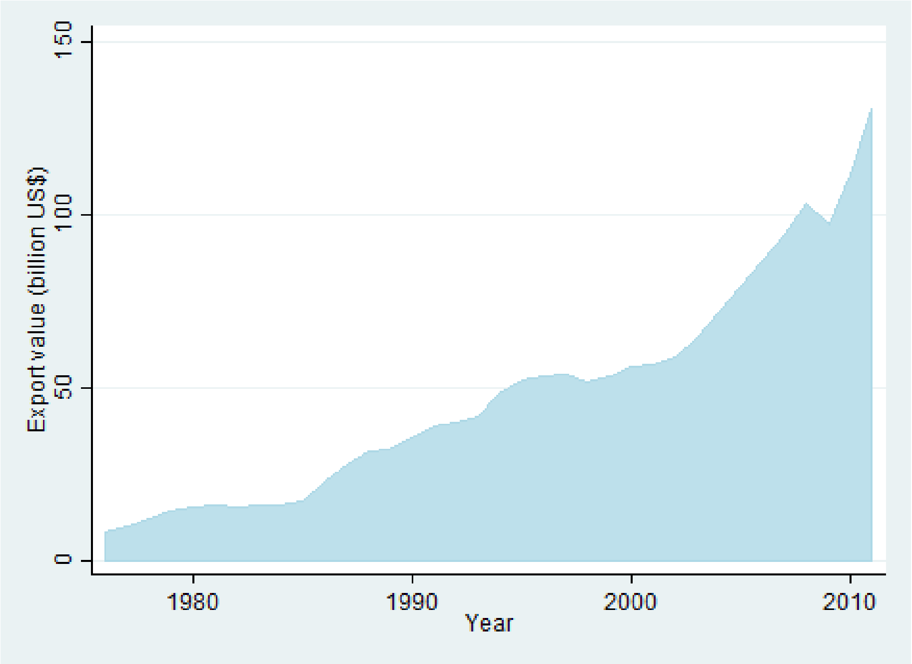
[39] Information on the value of a fishery's catch is incomplete. Hence, it is possible that a country's catch is more valuable than the sum of the value of a country's catch in different fisheries would suggest. Since the value of a country's total catch may be under-reported, the variable *Fishery percentage* has to be considered an upper bound and the importance of the fishery might actually be lower than reported here.

Figure 4.2: Export value in billion US$



4.13.2.2 Trade patterns

Trade in fisheries products has increased significantly over the sample period. The total value of trade increased from 8 billion US$ in 1976 to 130 billion US$ in 2011 (see Figure 4.2[40]). That is more than 16 times the initial value. According to FAO (2008), nearly 40 percent of global fish production is traded. Hence, trade is an important topic to consider.

The surge in trade in fisheries products coincides with an increasing prevalence of catch share programs. The total number of catch share programs increased from 30 in 1970 to 505 in 2013. This warrants the question whether there is any relationship between trade and fisheries management. Did international trade in fisheries products make resource management necessary or possible?

As a first step, we investigate whether managed and unmanaged fisheries differ in their trade patterns.[41] We look at trade data at the species level.

Exports: Since the dataset covers a range of different species, we focus on export values rather than export quantities. This facilitates comparisons

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[40] Note that the value of exports in this figure is not in constant US$ and includes trade in freshwater fish.

[41] Note that data coverage for trade data at the species level is incomplete. It is likely that trade data at the species level are only available for species with larger trade volumes. Trade in fish species with smaller trade volumes are lumped together into one category. We only us the trade data at the species level. This might introduce sample selection problems.

of trade data across species. Table 4.20 shows that the average export value in managed fisheries is 39 million US$, whereas unmanaged fisheries only export 20 million US$ worth of fish. Based on the results of a t-test displayed in Table 4.21, exports in managed fisheries are significantly higher than in unmanaged fisheries.

Figure 4.3 plots the average export value for adopters and non-adopters of catch share programs for every year from 1984 to 2003. The red dots show the average export value for non-adopters of catch share programs in the respective year. This group includes fisheries which introduce catch share programs at a later point in time as well as fisheries which do not introduce catch share programs during the sample period. The blue dots in Figure 4.3 show the average export value for adopters of catch share programs. In 1984, for example, two[42] Icelandic fisheries introduce catch share programs and the blue dot in Figure 4.3 reports the average export value of those two Icelandic fisheries in 1984.[43] The figure reveals that the fisheries which introduced catch share programs in 1990 and 1991 have particularly high export values. In both years, the average export value of fisheries which adopt management exceeds 100 000 tonnes. In 1990, we have data on the export value for 2 out of 9 fisheries which adopt management. One of those is the Atlantic cod fishery in Norway with an export value of 218 million US$. Moreover, two of the fisheries which adopt management in 1991 have very high export values. One of these fisheries is the Atlantic mackerel fishery in Norway with an export value of 269 million US$. The other fishery is the Atlantic cod fishery in Iceland with an export value of 709 million US$.

Imports: In most years, average imports in managed fisheries are slightly lower than average imports in unmanaged fisheries, as can be seen from Figure 4.4. The average import value in a fishery which adopts management is 14 million US$, whereas imports in the average unmanaged fishery are worth 28 million dollars. However, Table 4.21 shows that there is no statistically significant difference between the import value of fisheries which adopt management and fisheries which do not adopt management.

Net exports: On average, fisheries which introduce management are

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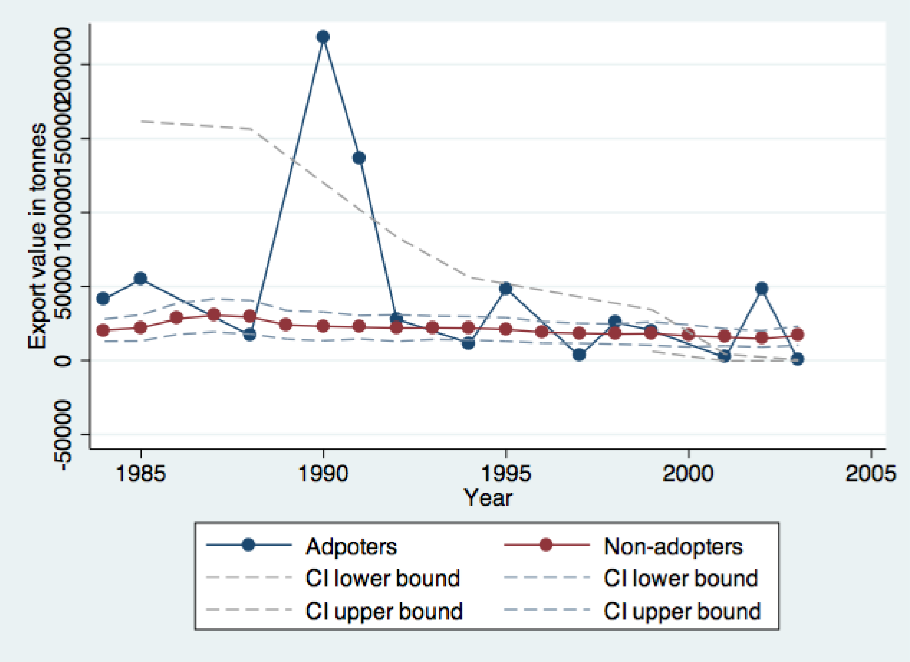
[42] Note that data coverage for the trade data at the species level is incomplete. Our dataset only provides information for those two fisheries for the year 1984, even though a larger number of fisheries introduced catch share programs in 1984.

[43] Since we only use the observations for which we have trade data at the species level, our sample only contains 70 observations which adopt management before 2003 and for which export data are available. Hence, the confidence intervals for the yearly averages larger. If the confidence intervals are too large, they are not displayed in the graph.

Figure 4.3: Average export value for adopters and non-adopters



net exporters. The average net exports of fisheries products in managed fisheries are worth 32 million US$ and weigh 13 000 tonnes (see Table 4.20). The average net exports amongst adopters of catch share programs are particularly high in 1991, due to the large net exports of Atlantic herring and mackerel in Norway and Atlantic cod in Iceland. Unmanaged fisheries have low net exports, on average. The average net export quantity is only 360 tonnes. The net export value is negative and the average unmanaged fishery imports 1.700 million US$'s worth of fish. The fact that net exports for adopters of catch share programs are significantly larger ties in with the finding that the export value tends to be slightly higher and the import value tends to be slightly lower for adopters of catch share programs than for unmanaged fisheries.

Exports/Production: The previous few paragraphs established that exports are significantly larger in managed fisheries. But are exports more important in managed fisheries in the sense that fisheries which adopt management export a larger fraction of their catch?

In order to asses this, we look at exports relative to domestic production at the species level. Domestic production includes both trade and aquaculture. Not all species are suitable for aquaculture production. Hence, we assume that aquaculture production is zero if FishStat J does not report aquaculture production of a particular species.[44]

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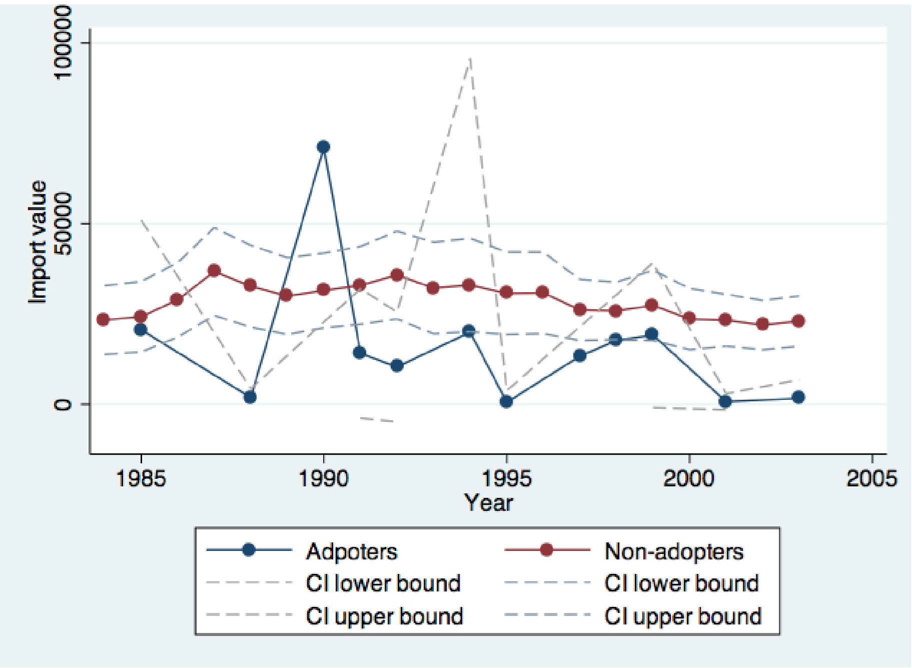
[44] If the data on aquaculture production are missing even though the country cultures

Figure 4.4: Average import value for adopters and non-adopters



In what follows, we focus on the export value relative to the value of domestic production. However, the same pattern holds if we look at export quantities. Table 4.20 shows that the average value of exports relative to the value of domestic production is 39 for fisheries which adopt management and 853.45 for unmanaged fisheries. However, the difference in the means between the two groups is not statistically significant, as demonstrated in Table 4.21.

The average export ratios are surprising large. They imply that exports exceed domestic production for the average fishery in both groups. Particularly for the unmanaged group, the ratio of exports relative to domestic production seem unrealistic. This variable, thus, deserves further scrutiny.

The high average ratio of exports relative to domestic production can be attributed to a few outliers with very high export ratios. Both amongst the managed fisheries and the unmanaged fisheries at least 5 percent of the observations report exports exceeding 1000 percent of the value of domestic production. Amongst the unmanaged fisheries, one percent of the observations have export ratios of more than 7 000 000 percent. The variable is very skewed and the observations with high export ratios lead to a high mean and standard deviation of the variable.

Since there are a lot of outliers with extremely high export ratios, the

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a particular species, our measure over-reports the proportion of exports relative to domestic production. Hence, the measure has to be considered an upper bound.

median is a more reliable measure than the mean. The median unmanaged fishery exports 29% of domestic production whereas the median managed fishery exports 77% of the value of domestic production. These numbers seem more realistic.

Three factors could explain why a few observations have high ratios of exports relative to domestic production. First of all, it is possible that countries engage in processing trade of a particular fish species. Asche and Smith (2009, p. 7) and Roheim (2005) argue that processing trade has become more prevalent in fisheries, due to improved freezing technology. "Thailand, for example, imports a significant amount of the world's tuna catches, processes it into cans and then exports it. Similarly, China is the major reprocessing market for U.S. and Norwegian seafood" (Roheim, 2005, p. 280).

With processing trade, domestic catch could be close to zero but exports could still be large. This would lead to a high ratio of exports relative to domestic production. However, the data do not suggest that the export ratios are particularly high for countries which engage in processing trade, like China and Thailand. The fisheries with export ratios exceeding 1000 do not include any fisheries in China. Only 1 of the fisheries with an export ratio of more than 1000 is in Thailand and 5 are in Poland. This implies that processing trade is unlikely to drive the very large outliers in the export ratios.

Missing aquaculture data offer another explanation for the high export ratios. As mentioned above, we assume that aquaculture production of species j in country i is zero if FishStat J does not report aquaculture production of species j in country i. If the data on aquaculture production are missing even though the country produces a particular species, our measure over-reports the proportion of exports relative to domestic production. It is not clear how complete the data coverage in the FishStat J aquaculture data is. Hence, the measure for exports relative to domestic production has to be considered an upper bound.

Finally, the unusually high export ratios could be due to differences in the classification of the nationality of the catch in the trade and catch data. One simple example can illustrate the point: Let us assume that a Spanish vessels fishes in British waters and then lands the fish in the UK. In the classification used for the FAO trade data, landings of domestic vessels into foreign ports are reported as exports. The FAO trade data would, thus, report the Spanish vessel's landings as a Spanish export into the UK. The

Sea Around Us catch database, on the other hand, maps the landings to the location in which the fish was caught. Hence, the landing by the Spanish vessel would be recorded as British catch.

We use capture production data from the FAO FishStat J's Global Commodities Production and Trade dataset to assess whether these classification differences concerning the nationality of the catch can explain the high export ratios. FAO FishStat J provides data on landed quantities (but not on landed values) and the nationality of the catch is based on the flag of the fishing vessel. Hence, the FAO capture production data are compatible with the trade data. When we calculate the openness measure using the FAO capture production data, the mean openness and the standard deviation are smaller. However, the data still suggest that a significant proportion of the fisheries has very high exports relative to domestic production.[45]

Openness: Are managed fisheries more open in the sense that they trade a larger fraction of their catch or domestic production? In order to investigate this, we use a measure of openness at the species level. Openness of country i with respect to trade in species j in year t is defined as

$$\text{Openness}_{ijt} = \frac{\text{Export value}_{ijt} + \text{Import value}_{ijt}}{\text{Catch (value)}_{ijt} + \text{Aquaculture (value)}_{ijt}} \tag{4.13}$$

Table 4.20 shows the average openness for adopters and non-adopters of catch-share programs. On average, the ratio of exports plus imports relative to domestic production is about 2 000 for unmanaged fisheries and about 120 for managed fisheries.[46] Both of these averages are much larger than expected and they are driven by outliers with extremely high openness values. The same factors which explain observations with large export ratios can also explain why the data record extremely high measures for trade openness: Processing trade, missing data on aquaculture and incompatibility between the trade and the catch data could all contribute to large openness values.

In light of the outliers with very high openness, the median could be a more informative measure about trade openness in the sample. The median openness measure for unmanaged fisheries is 1.2 whereas it is only 0.9 for managed fisheries.

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[45] Since data coverage on capture production in the Global Commodities Production and Trade dataset is incomplete, this can only be considered a rough test of whether the difference in the classification drives the observed pattern.

[46] The difference in the average openness between managed and unmanaged fisheries is not statistically significant (see Table 4.21).

Importance on the world market: The previous sections established that fisheries which adopt catch share programs are net exporters, that the absolute value of exports is significantly higher than in unmanaged fisheries and that the median managed fishery exports 77% of its domestic production. But how important are managed fisheries as seafood suppliers on the world market?

In order to assess this, we define country i's world market share of species j as the exports of species j by country i relative to the sum of exports of species j by all countries.

$$\text{World market share}_{ij} = \frac{\text{Exports of species } j \text{ from country } i}{\sum_i \text{Exports of species } j} \tag{4.14}$$

Based on this measure, fisheries which adopt catch share programs are not more important as suppliers on the world market than unmanaged fisheries. The variable *World market share* in Table 4.20 shows that fisheries which adopt management supply 22 percent of global exports of the species in question. The average unmanaged fishery supplies 17 percent of the supply on the world market. The difference between the two groups is small and not statistically significant, as shown in Table 4.21.

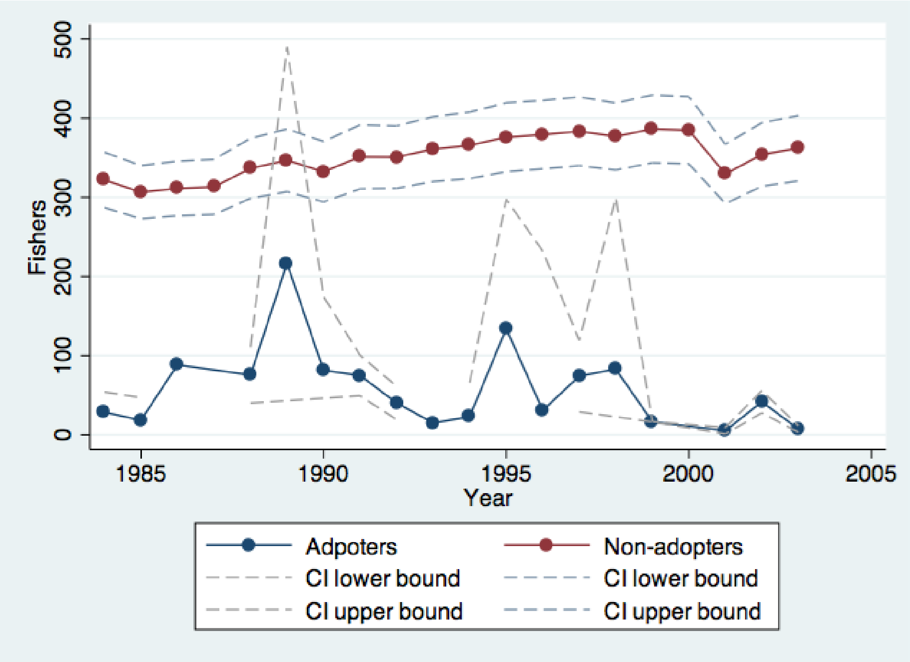
The fisheries which adopt management cover the whole spectrum from not exporting the product at all to being the only supplier on the world market. Our dataset provides information on the world market share for 69 fisheries which adopt management prior to 2007. 3 of those do not export and 5 are the only suppliers on the world market.

To summarize this section, we find that fisheries which adopt management are net exporters. Yet, we do not find that managed fisheries export a larger fraction of their domestic production than unmanaged fisheries. Moreover, there is no difference in the trade openness between managed and unmanaged fisheries and in their importance as suppliers on the world market.

4.13.2.3 Number of fishermen

Managed fisheries are in countries with a smaller number of fishermen. This has been shown in the summary statistics in Section 4.6. Figure 4.5 illustrates this in more detail. The red line in Figure 4.5 represents the average number of fishermen (at the country level) in unmanaged fisheries for every year between 1984 and 2003. The average number of fishermen in

Figure 4.5: Average number of fishermen for adopters and non-adopters



unmanaged fisheries is around 350 000 in most years.[47]

Fisheries which introduce catch share programs are in countries with significantly less fishers, as demonstrated by the blue line in Figure 4.5. Most of the catch share programs are introduced by countries with less than 100 000 fishermen. The United States and Mexico are the only countries in our sample which introduce catch share programs and have more than 100 000 fishermen.

The absolute number of fishermen may not accurately capture the importance of the fishing industry to a country's employment. China, for example, has a large number of fishermen but it has also got a large labour force. Hence, we look at the number of fishermen relative to the entire economically active population at the country-level in order to assess the importance of fishing for a country's employment. Table 4.20 shows that both adopters and non-adopters of catch share programs employ about one percent of their population in fisheries. Hence, the importance of fisheries as a source of employment does not seem to drive the introduction of catch share programs.

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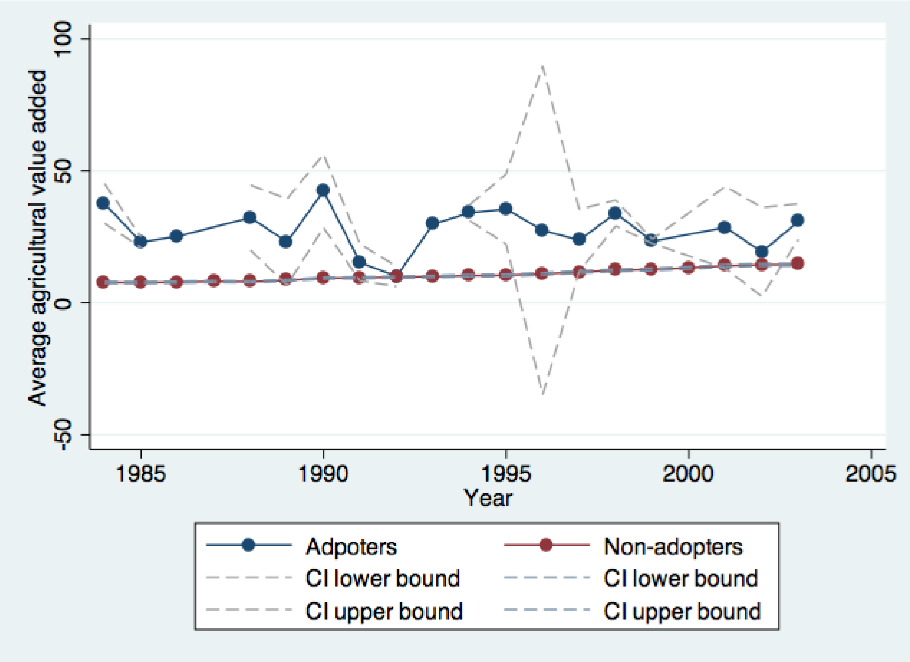
[47] Note that the countries with a larger number of fisheries get a greater weight when we calculate that average. This is the case for all country-level variables.

Figure 4.6: Average agricultural value added for adopters and non-adopters



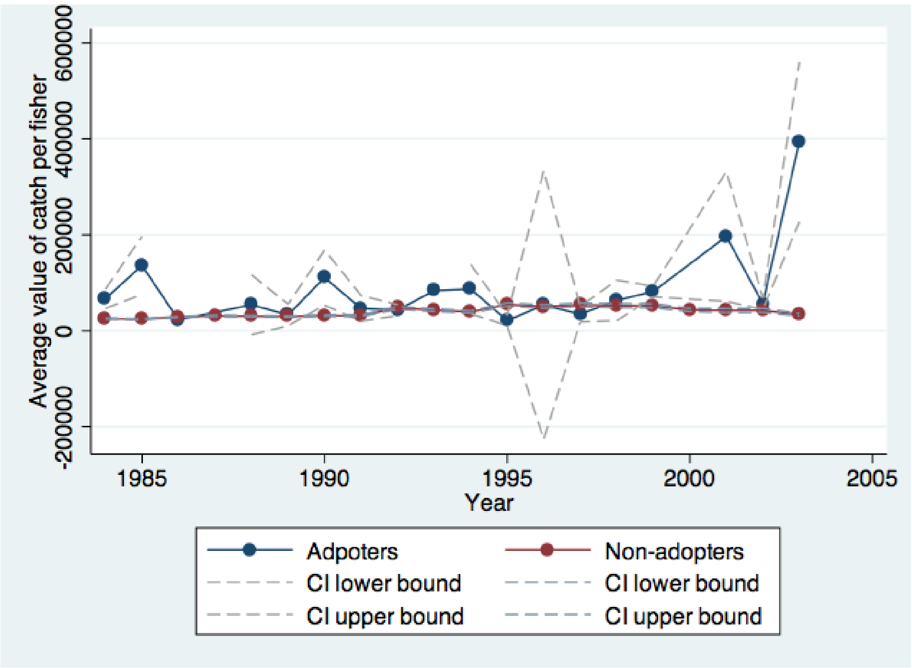
4.13.2.4 Technology

The stylized facts indicate that countries which introduce catch share programs are technologically more advanced. This holds for a range of indicators for fishing technology.

Lacking data on fishing vessels, fishing gears or devices such as fish finders, we proxy fishing technology using the agricultural value added per worker. Figure 4.6 shows the average agricultural value added for adopters and non-adopters of catch share programs from 1984 on. It is obvious from Figure 4.6 that the average agricultural value added for adopters of catch share programs, as represented by the blue line, is higher than the average agricultural value added per worker for non-adopters, represented by the red line. The latter increases from 7 700 constant US$ in 1984 to 14 500 constant US$ in 2006. The average agricultural value added for adopters is significantly higher than that in most years.

The value of the catch per fisherman can be used as an alternative proxy for technology. Table 4.20 shows that the average fisherman catches 40 000 US$ worth of fish in unmanaged fisheries. In fisheries which adopt catch share programs, the average value of the catch per fisherman is 88 000 constant US$. This is more than twice as much as the average catch per fishermen in unmanaged fisheries and the difference is statistically significant. Figure 4.7 reveals that the difference between the two groups is particularly striking at the end of the sample period. The fisheries which introduce

Figure 4.7: Average value of catch per fisherman



catch share programs in 2001 and 2003 are in countries with an average value of catch per fishermen of 200 000 and 400 000 US$ respectively. In unmanaged fisheries, the average value of the catch per fishermen is around 43 000 US$ and 33 000 US$ in those two years.

Countries which adopt catch share programs fare better along a range of other indicators for technology. Table 4.20 shows that managed fisheries have more patent and trademark applications, more researchers and technicians in R&D and their R&D expenditure as a percentage of GDP is significantly higher. The difference between managed and unmanaged fisheries is statistically significant for all of these variables (see Table 4.21).[48]

4.13.2.5 Fisheries collapse - details

In this section we investigate whether a large fraction of fisheries have collapsed prior to the introduction of catch share programs. Section 4.3.3 highlights that it is not clear whether whether fisheries collapse is more or less likely amongst adopters of catch share programs than in the unmanaged comparison group. On the one hand, anecdotal evidence suggests that countries introduce catch share program in response to declining fish stocks. In that case, the percentage of fisheries which have collapsed at the point at which management is introduced would probably be higher than the

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[48] Data on the number of patent and trademark applications and R&D expenditure are from the World Development Indicators.

percentage of fisheries which have collapsed in the unmanaged comparison group. On the other hand, governments may recognise the potential of rights-based management approaches and adopt catch share programs as a logical consequence of a successful history of managing a particular fishery. In the latter case, the percentage of fisheries which have collapsed prior to the introduction of management might be small.

In order to investigate the relationship between fisheries collapse and the adoption of catch share programs, we compare adopters of catch share programs to non-adopters for every year in our sample. The red line in Figure 4.8 shows the percentage of collapsed fisheries amongst the non-adopters of catch share programs. In 1984, 12 percent of the fisheries without catch share programs have collapsed. The data reveal a clear upward trend with an ever increasing percentage of collapsed fisheries. In 2003, 21 percent of the fisheries which were not managed via catch share programs have collapsed.

The picture looks better for the fisheries which adopted catch share programs. The percentage of collapsed fisheries amongst the fisheries which adopt catch share programs in a particular year is represented by the blue line in Figure 4.8. In many years, none of the fisheries for which governments implement catch share programs has collapsed at the point at which management is introduced. There are only 5 years in our sample period in which the percentage of collapsed fisheries was higher amongst adopters of catch share programs.

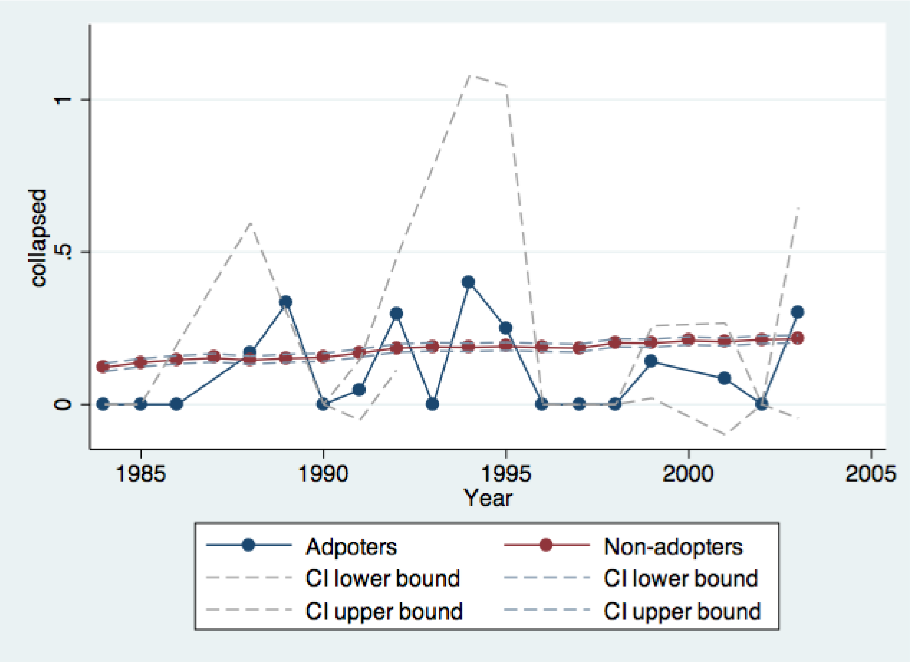
The same pattern follows through if we define fisheries as collapsed if the catch is less than 20 percent of the maximum catch since 1950. Moreover, the percentage of fisheries which have collapsed at any point in the past is lower amongst adopters of catch share programs.

The fact that fisheries collapse is less prevalent amongst the fisheries which adopt catch share programs implies that those fisheries are under less pressure than unmanaged fisheries. This could be due to better regulation prior to the introduction of catch share programs or due to lower fishing capacity relative to the fish stock.

4.13.2.6 Governance indicators

Fisheries are a common pool resource. In the absence of regulation, individuals have an incentive to overfish. Hence, some form of regulation is necessary. This regulation could either be based on social norms or on catch limits which are implemented and enforced by the government.

Figure 4.8: Percentage of collapsed fisheries for adopters and non-adopters



Customary use rights programs are rare and not considered in the context of this study. Governments, thus, play a crucial role in introducing the catch share programs which are investigated in this chapter.

We expect that governments with a history of implementing sound policies and regulations are also more likely to manage fisheries well and implement catch share programs. Moreover, countries with effective governments should be more likely to implement sound policies. In other words, we expect a country's regulatory quality and government efficiency index to be positively correlated with the introduction of catch share programs.

The World Bank's World Governance Indicators (WGI) provides information on regulatory quality. The WGI's regulatory quality index "[r]eflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development" (WGI, 2012).[49]

The summary statistics in Table 4.20 suggest that regulatory quality is higher in countries which introduce catch share programs. They reveal that the average regulatory quality index amongst the fisheries which adopt management is 1.50. Since the World Governance Indicators are measured on a scale from -2.5 to 2.5, these values are high. Unmanaged fisheries achieve an average score of 0.43. This is significantly lower than the score

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[49] The description of the variables can be downloaded by following the links to the respective variables on http://info.worldbank.org/governance/wgi/index.aspx#doc.

in managed fisheries (see Table 4.21).

Another potential proxy for a government's ability to implement good policies is the WGI's government effectiveness index, which "[captures] perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies" (WGI, 2012). The average government efficiency index in managed fisheries is 1.65, whereas unmanaged fisheries have a significantly lower average score of 0.51 (see Table 4.20).

These factors indicate that catch share programs are more prevalent in countries which are perceived to formulate sound policies. Governments in countries which adopt catch share programs are considered efficient governments in the sense that they are relatively independent from political pressure, formulate and implement good policies and that commitment to those policies is credible.

However, regulations are useless if they are not enforced. Copeland and Taylor (2009)'s model reveals that high enforcement power facilitates the adoption of catch share programs in an environment in which monitoring of landings is imperfect. It is, thus, insightful to look at the relationship between the adoption of management and indicators for enforcement power. One potential indicator for enforcement power is the rule of law index from the WGI dataset. In the context of our analysis, the rule of law index could be a good proxy for the extent to which fishermen can enforce the exclusive fishing rights assigned to them through quotas or territorial use rights programs.

The summary statistics show that adopters of catch share programs have significantly higher scores in the rule of law index. The average rule of law index in fisheries which adopt management is 1.60. This is significantly higher than the average rule of law index of 0.33 in unmanaged fisheries.

Enforcement of the law in courts is not the only aspect that matters for the enforcement of catch share programs. Landings of fish have to be monitored. In countries with high corruption, it is possible that fishermen land more than the quota allows them to catch and bribe the monitoring authority not to report the excessive catch. Hence, higher corruption is likely to hinder enforcement.

Moreover, corruption may impede the implementation of catch share programs. Individual fishermen may lobby against the introduction of catch share programs, since it limits the amount of fish they are allowed to catch.

Corruption might also allow fishermen to bribe officials for larger quotas. All of these factors suggest that corruption obstructs the implementation and enforcement of catch share programs. Hence, higher corruption may reduce a government's efforts to introduce catch share programs.

Data on corruption are available from the WGI dataset and from the International Country Risk Guide. We focus on the corruption indicator from the International Country Risk Guide since this index is available for a longer time period and is used in the empirical analysis in the main text.[50] The corruption indicator is rescaled so that it can take take values between -6 and 0. A higher value indicates that corruption is more prevalent. The average ICRG corruption score for fisheries which introduce catch share programs is -4.99 compared to an average corruption score of -3.55 in unmanaged fisheries. The difference between the two groups is statistically significant (see Table 4.21). This indicates that corruption is significantly lower in fisheries which introduce management.

Since the ICRG corruption indicator is used in the empirical analysis in this chapter, it is worth looking at the variable in more detail and checking whether the difference in corruption between the managed and unmanaged group is persistent throughout the sample period. Figure 4.9 plots the average ICRG corruption indicator for fisheries which adopt management as well as fisheries which do not adopt management. The graph highlights that there is a statistically significant difference between the two groups in most years.

To summarize, the data suggest that fisheries which adopt catch share programs are in countries with a record of implementing sound policies and with efficient governments, which are relatively independent from political pressure, formulate and implement good policies and whose commitment to these policies is credible. This credible commitment to policies is also reflected in the high rule of law indicator and in low corruption in fisheries which adopt management.

4.13.2.7 Resource-based economies

Finally, it is noteworthy that resource-based economies seem less likely to use catch share programs. Table 4.20 shows that resource rents as

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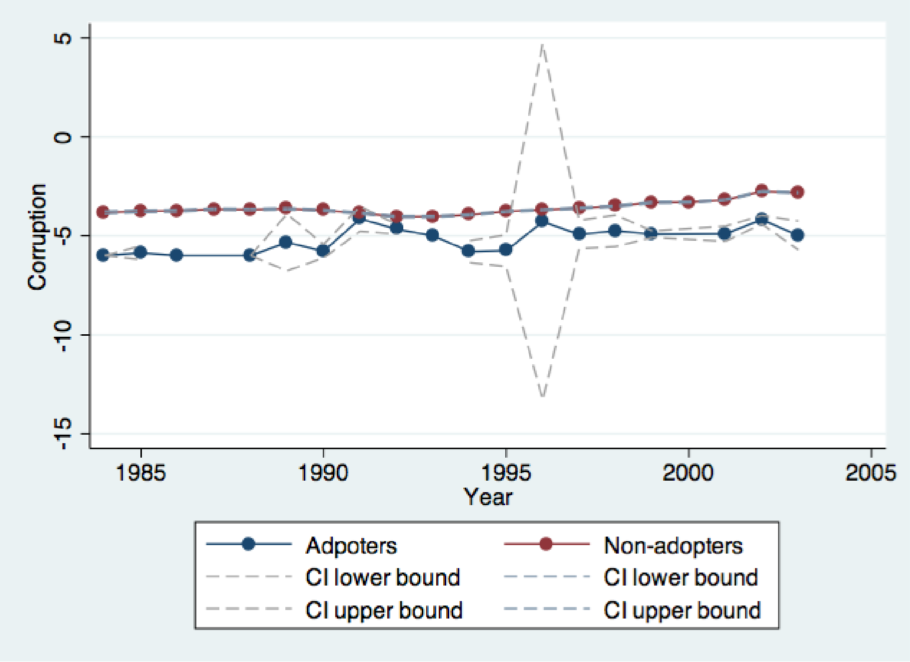
[50] The same results follow through using the corruption indicator from the World Governance Indicators. Table 4.20 shows that managed fisheries have a higher score in the corruption indicator. Since a higher score indicates better governance, corruption is lower in fisheries which introduce catch share programs. The difference between the two groups is statistically significant.

Figure 4.9: Average corruption for adopters and non-adopters



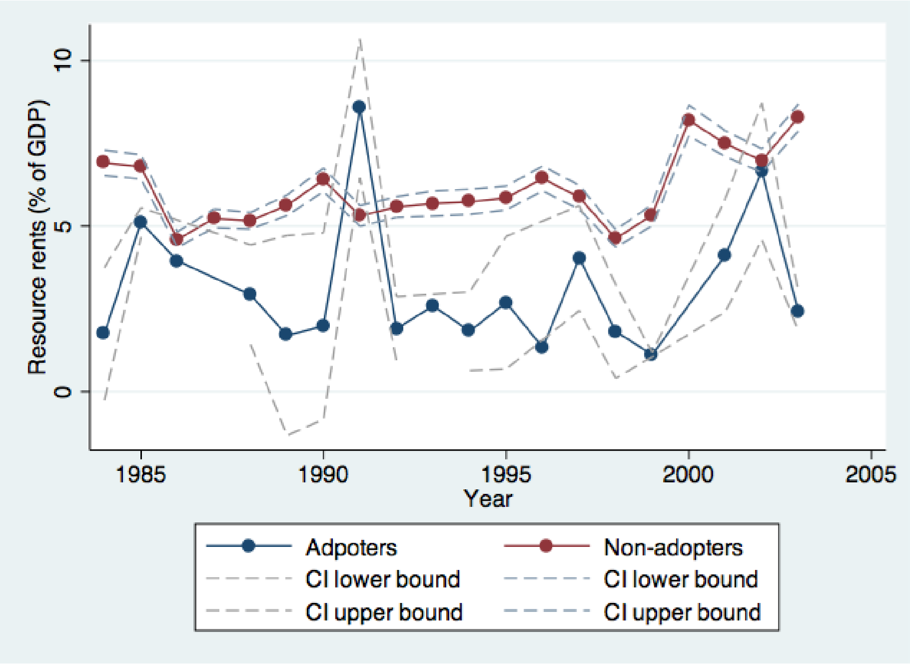
a percentage of GDP are significantly lower in countries which manage fisheries. Resource rents represent 6.17 percent of GDP in the average unmanaged fishery, whereas only 3.23 percent of GDP can be attributed to resource rents in fisheries which adopt management. Resource rents are high amongst the adopters of catch share programs in 1991 (see Figure 4.10), when Chile introduced catch share programs for several species. In 1991, resource rents contributed 12 percent to GDP in Chile.

4.13.2.8 GDP per capita

Anecdotal evidence suggests that poverty can be an important obstacle to fisheries management (see e.g. Satia and Jallow (2010) and Nandakumar and Nayak (2010) for evidence on West Africa and India, respectively). In poor countries, fisheries are often considered an important source of employment and they contribute to food security. Hence, countries with a lower GDP per capita, such as West African countries, often refrain from managing their fisheries sustainably and introducing catch share programs.

The data support the notion that GDP per capita is higher in countries which introduce catch share programs. The difference in GDP per capita between adopters of catch share programs and non-adopters on an annual basis is shown in Figure 4.11. The average GDP per capita for non-adopters increases from 11 500 in 1984 to 15 400 in 2003. This is represented by the red line in Figure 4.11. The blue line in Figure 4.11 highlights that catch

Figure 4.10: Average resource rents for adopters and non-adopters



share programs are introduced in countries with a significantly higher GDP per capita. The average GDP per capita in fisheries which introduce catch share programs over the course of the sample period is 25 400 US$ (see Table 4.20).

Figure 4.11: Average GDP per capita for adopters and non-adopters

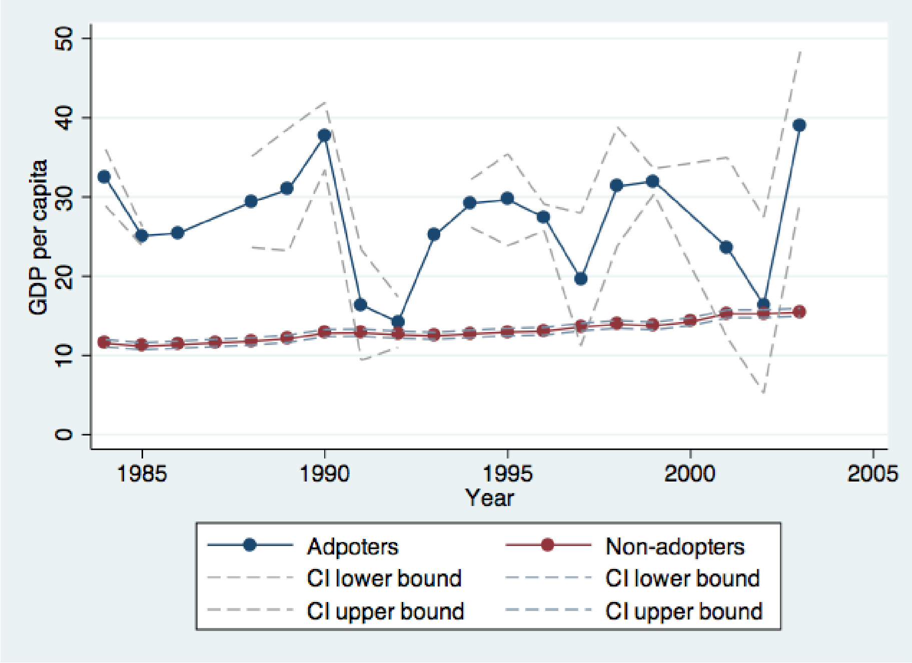


Table 4.24: Adoption of management programs by year

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

Table 4.25: Correlation table

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

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

4.13.3 Results appendix

The Results Appendix presents further empirical results and robustness checks.

4.13.3.1 Different specification of the baseline hazard

In the baseline model, we use a fully non-parametric specification of the baseline hazard. This section provides results for two alternative specifications of the baseline hazard. First of all, we use the log of the survival time to specify the baseline hazard. The result are presented in Column 1 of Table 4.26. Column 2 of Table 4.26 shows the results for a cubic polynomial specification of the baseline hazard. The result are of the same order of magnitude as the ones in our baseline regression.

4.13.3.2 Logit instead of cloglog

This section investigates whether our results are sensitive to the choice of the functional form of the baseline hazard. Instead of using a cloglog model, we use a logit model, in which the hazard rate can be written as

$$h(j, X) = \frac{exp(a_j + \beta X)}{1 + exp(a_j + \beta X)} \tag{4.15}$$

where $a_j = log\left[\frac{h_0(j)}{1-h_0(j)}\right]$.

The results for the logit model are displayed in Column 3 of Table 4.26. They show the same pattern as in baseline results.

4.13.3.3 Country-level results

So far, we have considered the adoption of catch share programs for every country-species combination as independent from the introduction of catch share programs for any other country-species combination. However, countries often introduce catch share programs for several species in the same year and it is not clear whether the decision to manage one species is completely independent from the decisions to manage another species. If there is a strong correlation in the factors which affect the introduction of catch share programs within a country, it is expedient to aggregate the data to the country-level. This should also give more accurate insights into the relationship between the country level control variables and a government's choice to introduce a catch share program.

Table 4.26: Sensitivity 1

	(1) Logistic	(2) Polynomomial	(3) Logit model
Managed			
Ln (Lagged price)	−0.210***	−0.205***	−0.206***
	(0.067)	(0.067)	(0.070)
Growth	−0.189	−0.191	−0.190
	(0.156)	(0.156)	(0.157)
Fishers	−0.004***	−0.004***	−0.004***
	(0.001)	(0.001)	(0.001)
GDP p.c.	−0.011	−0.016	−0.016
	(0.011)	(0.011)	(0.012)
Agri VA	0.029***	0.029***	0.031***
	(0.009)	(0.009)	(0.009)
Corruption	−0.677***	−0.743***	−0.742***
	(0.108)	(0.119)	(0.123)
Coastline	0.027*	0.025*	0.026*
	(0.014)	(0.014)	(0.015)
Collapsed	−0.605***	−0.617***	−0.617***
	(0.224)	(0.224)	(0.226)
Resource rents	0.002	0.002	0.005
	(0.013)	(0.013)	(0.013)
lnj	0.167		
	(0.122)		
j		0.063	
		(0.162)	
j2		−0.005	
		(0.017)	
j3		0.000	
		(0.001)	
Observations	63155	63155	56816
Managed	179.000	179.000	

Standard errors in parentheses

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

We use a survival model at the country level. The dependent variable takes a value of one as soon as a country introduces a catch share program for the first species. 11 countries in our sample introduce the first catch share program between 1984 and 2003. The species level control variables are aggregated to the country level using an unweighted average.

The regression results are displayed in Column 1 of Table 4.27. They suggest that the fish population growth rate and the length of the coastline are the only statistically significant determinants of the adoption of catch share programs.

Aggregating to the country level leads to a large loss of information. Firstly, we lose information about the species level regressors. Secondly, we lose information on the precise year in which countries introduce catch share programs since we classify countries as adopters as soon as they have introduced the first catch share program. 4 of the 15 countries in our sample introduce catch share programs prior to 1984. Those countries are not included in the sample and the results could be biased due to delayed entry. The respective countries are Australia, Canada, Iceland and Norway. Those countries are considered poster child adopters of catch share programs and they introduce a considerable amount of catch share programs from 1984 on. Not including these countries in the analysis could affect the results.

Instead of aggregating to the country level, we can use species-level data and cluster the standard errors at the country level. Clustering standard errors at the country level leads to correct inference even if the unobserved error terms are correlated within countries. Column 2 of Table 4.27 shows the results for a regression using the species-level data in combination with cluster-robust standard errors. The pattern is very similar to the results in the baseline regression in Column 1 of Table 4.10. The introduction of catch share programs is negatively correlated with the price, the number of fishermen, corruption and the variables which indicates that a fishery has collapsed.

4.13.3.4 Clustering at the species level

It is possible that unobservable factors which foster or hinder the introduction of catch share programs are correlated within species across countries. This could be the case if two or more countries share a fish stock and decide to introduce catch share programs in the same year, for example. The correlation of error terms within species warrants clustered standard errors at the species level.

Table 4.27: Country level and clustered results

	(1) Agg	(2) Country-cluster	(3) Species-cluster
Ln (Lagged price C)	−0.569		
	(0.811)		
Ln (Lagged price)		−0.204 ∗ ∗	−0.204 ∗ ∗
		(0.098)	(0.083)
Growth C	−4.983∗		
	(2.887)		
Growth		−0.187	−0.187
		(0.117)	(0.148)
Fishers	−0.005	−0.004 ∗ ∗	−0.004∗∗∗
	(0.006)	(0.002)	(0.001)
GDP p.c.	0.002	−0.015	−0.015∗
	(0.063)	(0.031)	(0.008)
Agri VA	0.029	0.030	0.030∗∗∗
	(0.061)	(0.028)	(0.008)
Corruption	−0.454	−0.732∗∗∗	−0.732∗∗∗
	(0.436)	(0.167)	(0.092)
Coastline	1.643 ∗ ∗	0.025	0.025∗
	(0.812)	(0.021)	(0.013)
Percentage collapsed C.	−4.168		
	(3.233)		
Collapsed		−0.611 ∗ ∗	−0.611 ∗ ∗
		(0.284)	(0.242)
Resource rents	−0.096	0.005	0.005
	(0.084)	(0.021)	(0.006)
Observations	543.000	56816.000	56816.000
Managed	11.000	179.000	179.000

Standard errors in parentheses

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

Column 3 of Table 4.27 presents the results of the baseline regression with standard errors clustered at the species level. A comparison of those results with the results in Column 1 of Table 4.10 reveals that clustering at the species level leads to slightly larger standard errors for the variables which vary at the species level. However, the difference in the standard errors is small and we get the same significance pattern as in the baseline regression.

4.13.3.5 A cross-sectional approach

Instead of using a survival model which pools the observations for a time-period of 20 years, it is possible to use a cross-sectional approach and compare fisheries which adopt management to non-adopters in every year in the sample separately. Since the panel is relatively long, this approach could be beneficial as it ensures that we do not compare fisheries at the end of the sample period to fisheries at the beginning of the sample period.

Due to the small number of fisheries which adopt management in every year, we pool observations for five year intervals and analyse the determinants for the introduction of catch share programs for each of those time periods separately. The intervals are 1984 to 1988, 1989 to 1993, 1994 to 1998 and 1999 to 2003.

The results for a baseline regression for each of those sample periods are shown in Table 4.28. The relationship between the coefficient estimate for the price variable is negative for the first, the second and the last time period. Yet, only the coefficient estimate for the period from 1999 to 2003 is statistically significant. For the time period from 1994 to 1998, we find a positive but statistically insignificant relationship between the price and the hazard rate. This is may be due to the introduction of catch share programs for a few higher value species like lobsters, crabs and clams during that time period.

4.13.3.6 Different control variables

This section tests the sensitivity of our result to the use of different proxy variables for technology, fisheries collapse and the number of fishermen.

4.13.3.6.1 Different measure for technology The baseline model uses agricultural value added as a proxy for fishing technology. However, this measure does not only capture fishing technology but agricultural technology in general. In this section, the catch per fisherman is used as an alternative

Table 4.28: Cross-sectional approach

	(1) 1984-88	(2) 1989-93	(3) 1994-98	(4) 1999-2003
Managed				
Ln (Lagged price)	−0.344	−0.009	0.062	−0.324∗∗∗
	(0.225)	(0.112)	(0.208)	(0.117)
Growth	−1.251	0.094	−1.247	−0.362
	(1.093)	(0.159)	(0.992)	(0.368)
Fishers	−0.149	−0.002	−0.001	−0.018∗∗∗
	(0.095)	(0.001)	(0.002)	(0.007)
GDP p.c.	−0.021	−0.023	−0.036	−0.004
	(0.054)	(0.024)	(0.036)	(0.018)
Agri VA	0.086∗∗∗	0.052∗∗∗	0.049∗	−0.003
	(0.031)	(0.019)	(0.028)	(0.015)
Corruption	−1.794∗	−0.259	−0.537	−0.930∗∗∗
	(1.029)	(0.222)	(0.343)	(0.200)
Coastline	0.641∗	0.011	0.084 ∗ ∗	−0.009
	(0.388)	(0.028)	(0.035)	(0.040)
Collapsed	−1.611	−0.094	−0.796	−0.825 ∗ ∗
	(1.023)	(0.348)	(0.615)	(0.359)
Resource rents	0.107	0.011	−0.003	−0.018
	(0.091)	(0.019)	(0.042)	(0.023)
Managed	25.000	61.000	27.000	66.000
Observations	10238.000	14991.000	16353.000	15234.000

Standard errors in parentheses

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

Table 4.29: Sensitivity to control variables

	(1) Catch/F	(2) Collapsed
Managed		
Ln (Lagged price)	-0.104	-0.206***
	(0.0737)	(0.0693)
Growth	-0.137	-0.187
	(0.151)	(0.156)
Fishers	-0.00416***	-0.00422***
	(0.00126)	(0.00127)
GDP p.c.	0.00699	-0.0156
	(0.00950)	(0.0114)
L.Catch per fisherman	0.000000444	
	(0.000000552)	
Agri VA		0.0294***
		(0.00898)
Corruption	-0.650***	-0.742***
	(0.133)	(0.122)
Coastline	0.0550***	0.0258*
	(0.0140)	(0.0145)
Collapsed	-0.596**	
	(0.235)	
Collapsed (20 perc.)		-0.725***
		(0.192)
Resource rents	-0.00145	0.00398
	(0.0137)	(0.0128)
Observations	50853	56816
Managed	159	179

Standard errors in parentheses

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

proxy for fishing technology. Holding everything else constant, fishermen with more advanced technology should be able to catch more. Unfortunately, the catch per fisherman does not only capture technology but also the stock size. If fish stocks are small or a fishery has collapsed, even a very advanced technology would not allow the fishermen to land large quantities of fish. Hence, the variable is likely to represent both, the stock size and fishing technology.

The catch per fisherman is measured in US$ per fisherman and the variable is constructed at the country level. Catch data are from Swartz et al. (2012), who use information on landings from the *Sea Around Us* catch database. We aggregate the value of landings for all species within a country for every year and divide the country-level value of landings by the number of fishermen.

Catch share programs introduce catch limits for individual fishermen or vessels. Hence, the introduction of catch share programs is likely to affect the catch per fisherman. In oder to avoid reverse causality, we use the catch per fisherman in period $t-1$ as a regressor.

Column 1 of Table 4.29 shows the results for a regression using the lag of the catch per fisherman instead of agricultural value added as a control variable. Catch per fisherman is not significantly correlated with a the hazard rate for the introduction of catch share programs. However, the results suggest that the likelihood of introducing catch share programs increases in GDP per capita, which is highly correlated with the indicators for technology. It is possible that the coefficient estimate for GDP per capita picks up the positive effect of technology on the introduction of catch share programs. All other coefficient estimates are similar to the coefficient estimates of the baseline regression.

4.13.3.6.2 Different measure for fisheries collapse In the baseline model, a fishery is defined as collapsed when the catch it less than 10 percent of the maximum catch since 1950. This section investigates the robustness of our results to the measure for fisheries collapse. We use a more lenient approach and define a fishery as collapsed as soon that the catch is below 20 percent of the maximum catch since 1950. The results are presented in Column 2 of Table 4.29. They indicate that a collapsed fishery is 0.72 percent less likely to be managed. This coefficient estimate is only slightly larger than the coefficient estimate for the dummy variable which indicates fisheries collapse in the baseline regression.

4.13.3.6.3 Fishermen relative to the economically active population

Thus far, our results suggest that a smaller number of fishermen is favourable for the introduction of catch share programs. However, the absolute number of fishermen does not inform us about the importance of the fishing industry as a source of employment in a particular country. In order to capture the significance of fisheries in a country's labour market, we control for the number of fishermen relative to the economically active population.[51] This variable replaces the absolute number of fishermen which was used in the baseline regression. Ex ante, it is not clear whether a larger number of fishermen relative to the economically active population hinders or fosters the introduction of catch share programs. A social planner should introduce catch share programs if he wants to avoid overfishing, guarantee the sustainability of the fishing industry and make sure that fishing stays a viable and profitable source of income in the long run. The importance of good regulation should be more obvious if the fishing industry provides a larger proportion of total employment.

In the short run, however, the introduction of catch limits may make fishing less profitable and force some fishermen to leave the industry. Fishermen might lobby against the introduction of regulations and their concerns are likely to attract more attention if the number of fishermen relative to the economically active population is higher.

The regression results in Column 2 of Table 4.30 show that governments are more likely to introduce catch share programs if the fishing industry is an important source of employment. An increase in the number of fishermen relative to the economically active population by 1 percent is associated with an increase in the hazard rate of 0.23 percent. The standard deviation of the number of fishermen relative to the economically active population is 0.0097, and hence an increase in the number of fishermen by one standard deviation is estimated to raise the hazard rate by 0.22 percent. Thus, the number of fishermen relative to the economically active population cannot explain as much of the variation in management as the absolute number of fishermen.

According to those results, countries are more likely to manage fisheries if more of their workforce is employed in fisheries. Iceland is a classic example for this phenomenon. Iceland employs a larger fraction of its workforce in fisheries than most other countries in the sample and the fisheries sector is important for the Icelandic economy. The decline of the cod and herring

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[51] Data on the economically active population are from the FAO Stat and are available on `http://faostat.fao.org/site/452/default.aspx`.

Table 4.30: Sensitivity to control variables

	(1) F/Active	(2) F/Coastline	(3) Active	(4) EKC
Managed				
Ln (Lagged price)	-0.172**	-0.198***	-0.199***	-0.232***
	(0.071)	(0.068)	(0.070)	(0.071)
Growth	-0.208	-0.178	-0.205	-0.197
	(0.157)	(0.153)	(0.159)	(0.159)
Fi/Active	20.328***			
	(6.905)			
Fi/Coast		-0.006***		
		(0.001)		
Economically active			-0.007**	
			(0.003)	
GDP p.c.	-0.019*	-0.034***	-0.018	0.032
	(0.011)	(0.010)	(0.011)	(0.026)
GDP pc^2				-0.001**
				(0.000)
Agri VA	0.023**	0.028***	0.035***	0.027***
	(0.010)	(0.008)	(0.009)	(0.009)
Corruption	-0.957***	-0.764***	-0.808***	-0.700***
	(0.117)	(0.107)	(0.122)	(0.123)
Coastline	0.017		0.010	0.020
	(0.014)		(0.013)	(0.015)
Collapsed	-0.580***	-0.630***	-0.608***	-0.609***
	(0.225)	(0.224)	(0.224)	(0.224)
Resource rents	0.010	0.011	0.007	0.014
	(0.012)	(0.013)	(0.013)	(0.013)
Observations	56812	56816	56816	56816
Managed	179.000	179.000	179.000	179.000

Standard errors in parentheses

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

stocks had drastic consequences for the Icelandic economy (Matthiasson and Agnarson, 2010, p. 299) and Iceland introduced quota systems for most of its fisheries.

Even though fisheries are an important source of employment in Iceland, the absolute number of Icelandic fishermen is small, with an average of around 6500 during the sample period. This example shows that the finding of a positive coefficient estimate for the variable "Fi/Active" can be reconciled with a negative coefficient estimate for the variable "Fishers" which represents the absolute number of fishermen.

4.13.3.6.4 Fishermen relative to the length of the coastline In the baseline regression, a larger number of fishermen is found to have a negative effect on the adoption of catch share programs. In order to assess whether this is due to higher pressure on fisheries, we scale the number of fishermen by the length of the coastline. A larger number of fishermen relative to the length of the coastline would imply higher pressure on fisheries.

The results are presented in Column 3 of Table 4.30. They confirm the idea that high fishing pressure is not conducive to the introduction of catch share programs. The countries with a larger number of fishermen relative to the length of the coastline are significantly less likely to introduce catch share programs.

4.13.3.6.5 Economically active population Copeland and Taylor (2009)'s model suggest that the introduction of fisheries management is more likely if the labour force which could potentially go fishing is smaller. Even though fishing requires a particular skill set, one could argue that everyone who participates in the labour force could learn those skills and become a fisherman. Therefore, we conduct a robustness check using the economically active population, measured in millions, as a proxy for the labour force which could go fishing instead of the number of fishermen. The results are displayed in Column 3 of Table 4.30. The confirm the negative relationship between the labour force which could potentially go fishing and the introduction of catch share programs.[52]

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[52] The same pattern follows through if we use the economically active population in agriculture as a proxy for the labour force which could potentially participate in the fishery.

4.13.3.7 Environmental Kuznets Curve for fisheries management?

The Environmental Kuznets Curve (EKC) literature argues that there may be an inverse U-shaped relationship between GDP per capita and environmental quality.[53] A similar phenomenon could apply to fisheries. It is possible that the likelihood of introducing a catch share program first declines and then increases with per capita income. In high income countries, a high demand for environmental quality could foster the introduction of catch share programs.

In order to investigate whether there is an EKC for the introduction of catch share programs, we added GDP per capita squared as a regressor to the baseline model. The regression results are presented in Column 4 of Table 4.30. The coefficient estimate for GDP per capita squared is statistically significant and negative.

We calculate the marginal effect for the likelihood of introducing a catch share program for different values of GDP per capita. Since GDP per capita ranges between 1100 US$ and 62 000 US$ in our sample, Figure 4.12 shows the average marginal effects for values of GDP per capita up to 65 000 US$. The Figure reveals an EKC like U-shaped relationship between GDP per capita and fisheries management. However, the 95% confidence intervals include 0 for most values of GDP per capita. Therefore, we cannot conclude that per capita income has a statistically significant effect on the introduction of catch share programs in that income range.

4.13.3.8 Results with interaction terms

Section 4.9.4 investigates whether the data lend support to Copeland and Taylor (2009)'s model. This section explores this further. Instead of using two interaction terms between the price and corruption and between the price and our measure for overcapacity, we interact the price with one of the country or fisheries characteristics at a time so as to avoid multicollinearity.

According to Copeland and Taylor (2009)'s model, an increase in the price facilitates the introduction of fishing quotas if enforcement power is high or corruption is low. Hence, the model predicts a negative coefficient estimate for the interaction term between the price and corruption *P*Corruption*. The results reveal the opposite. An interaction term between the price and corruption was already discussed in Section 4.9.2 and Column 1 of Table

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[53] See e.g. Grossman and Helpman (1993) for an early empirical contribution in the EKC literature and Copeland and Taylor (2003) for a theoretical derivation of the EKC phenomenon.

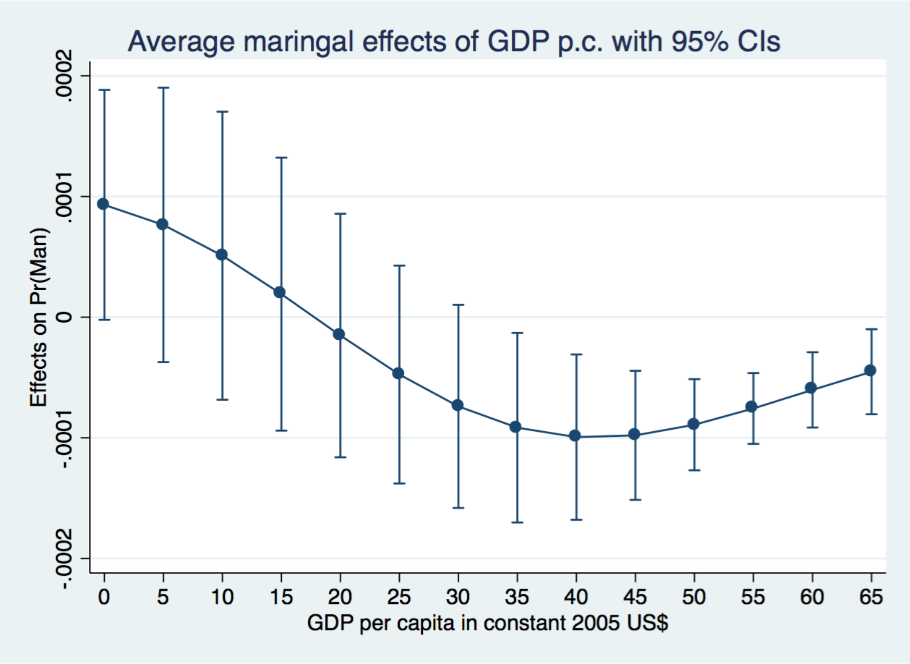
Table 4.31: Cloglog model - Interaction terms

	(1)	(2)	(3)	(4)	(5)
Managed					
Ln (Lagged price)	−0.155*	−0.230***	−0.147	−0.242***	−0.224***
	(0.089)	(0.081)	(0.130)	(0.076)	(0.074)
Growth	−0.148	−0.188	−0.185	−0.192	−0.189
	(0.163)	(0.156)	(0.156)	(0.155)	(0.156)
Fishers	−0.004***	−0.004***	−0.004***	−0.004***	−0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
GDP p.c.	−0.015	−0.015	−0.015	−0.015	−0.015
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Agri VA	0.030***	0.030***	0.031***	0.030***	0.030***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Corruption	−0.732***	−0.732***	−0.728***	−0.733***	−0.732***
	(0.122)	(0.122)	(0.122)	(0.122)	(0.122)
Coastline	0.025*	0.025*	0.024	0.023	0.025*
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Collapsed	−0.606***	−0.611***	−0.613***	−0.609***	−0.662***
	(0.225)	(0.224)	(0.224)	(0.224)	(0.238)
Resource rents	0.005	0.005	0.005	0.005	0.005
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
P × Growth	−0.119				
	(0.134)				
P × Fishers		0.001			
		(0.001)			
P × Agri VA			−0.003		
			(0.005)		
P × Coastline				0.013	
				(0.011)	
P × Collapsed					0.162
					(0.208)
Observations	56816.000	56816.000	56816.000	56816.000	56816.000

Standard errors in parentheses

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

Figure 4.12: Maringal effects for different values of GDP p.c.



4.17 shows that an increase in the price fosters the introduction catch share programs more in corrupt countries.

In the context of Copeland and Taylor (2009)'s model, an increase in the price would only lead to the introduction of resource management if the resource grows fast, the number of fishermen is small and the fishing technology is not advanced. We proxy fishing technology with agricultural value added.

The results for interaction terms between the price and the respective proxies for overcapacity in Columns 1-3 of Table 4.31 do not lend support to Copeland and Taylor (2009)'s model. None of the interaction terms is statistically significant. This implies that the relationship between the price and the introduction of catch share programs does not depend on the factors which determine overcapacity in Copeland and Taylor (2009).

The theory by Copeland and Taylor (2009) does not model the length of the coastline. Yet, a longer coastline gives a country access to larger fishing grounds. Holding everything else constant, a longer coastline reduces overcapacity. According to a loose interpretation of the model, an increase in the price should, thus, lead to the adoption of catch share programs in a country with a longer coastline. However, the relationship between the price and the adoption of catch share programs does not seem to depend on the length of the coastline. The coefficient estimate of the interaction term *P*Coastline* in Column 4 of Table 4.31 is not statistically significant.

Moreover, fisheries collapse is a good indicator for overcapacity in a fishery. In most cases, fisheries collapse is the results of overfishing and it indicates that the number of fishermen was too large and the fishing technology too advanced relative to the stock's capacity to replenish. The results in Column 5 of Table 4.31 support our previous finding that the relationship between the price and catch share programs does not seem to depend on overcapacity. The coefficient estimate for the interaction term *P*Collapsed* is not statistically significant.

Table 4.32: Summary statistics by availability of trade data

	(1) No Trade Data mean	sd	(2) Trade Data mean	sd
Managed	0.00	0.05	0.02	0.13
Ln (Lagged price)	0.41	1.08	0.62	1.12
Growth	0.51	0.75	0.37	0.37
Fishers	370.38	1197.45	162.33	655.41
GDP p.c.	12.21	13.36	24.46	13.66
Agri VA	10.12	12.06	19.06	12.52
Corruption	-3.48	1.32	-4.45	1.29
Coastline	1.25	2.99	1.14	2.48
Collapsed	0.18	0.38	0.21	0.41
Resource rents	6.44	10.39	2.24	4.92
Observations	51998		3072	

Table 4.33: T-test for difference in means by availability of trade data

	(1)	
Managed	-0.0159***	(-15.04)
Ln (Lagged price)	-0.206***	(-10.24)
Growth	0.148***	(10.84)
Fishers	208.1***	(9.55)
GDP p.c.	-12.25***	(-49.34)
Agri VA	-8.940***	(-39.83)
Corruption	0.965***	(39.47)
Coastline	0.109*	(1.98)
Collapsed	-0.0297***	(-4.17)
Resource rents	4.198***	(22.25)
Observations	55070	

t statistics in parentheses

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

5 Conclusion to the thesis

International trade can exacerbate pollution in countries which export polluting products if countries fail to internalize the environmental externality.[1] For exporters of renewable resources, trade can be associated with overharvesting in the absence of well-defined property rights for the resource (Chichilnisky, 1994; Brander and Taylor, 1997b,a). It is, thus, not surprising that environmentalists often oppose trade liberalization for fear of negative environmental consequences.

Given the potential adverse effects of trade on environmental outcomes, this thesis examines regulatory options for governments in countries which engage in international trade but fail to use domestic policies to internalize the distortions resulting from pollution or open access to renewable resources.

The first part of the thesis studies optimal trade policy for countries which cannot implement or enforce the first best environmental policy. The theoretical model in Chapter 2 shows that trade barriers can be used as a second-best instrument to reduce pollution. This holds both for import tariffs and for export taxes. The second-best export tax increases in a product's pollution intensity. The intuition behind this result is simple: The production of pollution-intensive goods which are subject to an export tax declines when the export tax is raised. As a consequence, resources shift into less damaging activities, thus, reducing overall pollution.

The empirical evidence from Chapter 3 of the thesis suggests that China uses partial VAT rebates as a second-best environmental policy instrument to reduce water pollution and energy use. We find that the VAT tax is higher for industries with a higher water pollution intensity, and energy intensity between 2007 and 2009. This pattern is in line with the actions of a regulator who adjusts the overall export tax to reduce exports of water-pollution intensive and energy intensive products. Moreover, China seems to use trade policy to promote the conservation of natural resources. From 2007 on, the VAT tax is significantly higher for metals, mineral products, wood products and precious stones than for non-resource products.

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[1] Details were highlighted in the introduction to the thesis in Chapter 1.

However, there is little evidence that the export tax is used as a secondary instrument to reduce pollution or conserve natural resources. The export tax seems to be motivated by an attempt to protect downstream producers in China, since the export tax is higher for primary products.

The work on trade policy as second-best environmental policy highlights that it may be welfare-enhancing to deviate from the first-best trade policy if domestic regulation fails to internalize the environmental distortion. Particularly developing countries which struggle to enforce domestic environmental regulation could benefit from the use of trade policy as a way of internalizing the distortion. The cost of implementing and enforcing a tariff or an export tax is likely to be lower than the collection of pollution taxes.[2]

The use of import tariffs as second-best option is difficult for members of the WTO if the second-best tariffs exceed the bound tariffs. However, export taxes may be a viable option, since the WTO does not restrict the introduction of export taxes.

Indeed, China is not the only country which uses export taxes to conserve the environment. Piermartini (2004) highlights that particularly least developed countries impose export taxes, mostly on agricultural, forestry and fishery products as well as minerals and metals.

The use of trade barriers for environmental reasons and for the conservation of renewable resources such as fisheries and forests assumes that environmental policy is exogenous. However, trade can affect institutions. Chapter 4 of the thesis investigates this for the case of renewable resources.

Several theoretical papers link the management of renewable resources to exports of fisheries products. The literature focuses on small exporters of fisheries products and models a country's opening up to trade as an exogenous increase in the (relative) price of fish. Several mechanisms via which this change in the price can affect resource management were proposed by the literature. One stream of the literature argues that an increase in the price is harmful for resource management (Sethi and Somanathan, 1996; Barbier et al., 2005). Demsetz (1967); Hotte et al. (2000); Tajibaeva (2012) and Copeland and Taylor (2009), on the other hand, show different channels via which an increase in the price could lead to the adoption of resource

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[2] See e.g. Karapinar (2011). Greenaway (1980) argues "that the fiscal needs of many less developed countries (LDCs) are met by a greater reliance on indirect taxes [such as trade taxes] than on direct taxes; principally because of the relatively high collection/ administrative costs associated with the latter" (Greenaway, 1980, p. 175). This reasoning should also apply to pollution levies, since the institutional and human capital requirements associated with firm level pollution levies are likely to he higher than the collection of export taxes at ports.

management or the enforcement of property rights.

Such conflicting theoretical predictions warrant empirical evidence. To the best of our knowledge, Chapter 4 of this thesis conducts the first empirical analysis on the effect of trade on the management of a renewable resource. We analyse factors which motivate governments to introduce catch share programs for fisheries and we use a novel dataset which allows us to investigate the question at the country-species level.

Our baseline model follows the theoretical literature closely and focuses on the relationship between the price and fisheries management. The results show a robust negative relationship between the price and the introduction of catch share programs. Three mechanisms can potentially explain this finding. Firstly, an increase in the price could lead to a collapse of social norms and, thus, hamper fisheries management. Secondly, a higher price could foster lobbying efforts against catch limits and, thus, halt their introduction, particularly in corrupt countries. Thirdly, the result could be explained by different fishing costs across species. Low fishing cost per kilo of catch could also explain why the average landed weight is considerably higher in fisheries which introduce catch share programs. This thesis cannot provide a definite answer which of these channels prevails, mostly due to a lack of relevant data on lobbying efforts and fishing costs.

Further research is necessary to understand the factors which drive the negative relationship between the price and the introduction of catch share programs. The collection of data on fishing costs would be a first step in that direction. The empirical analysis could also be refined through the use of an instrumental variable for the price. Even though we conduct a series of robustness check to investigate any sort of bias in the price variable, our empirical analysis cannot establish causality.

The theoretical literature on trade in renewable resources looks at small exporters of fisheries products and argues that an increase in the price is the result of reduced barriers to trade. Yet, changes in the price can be caused by other factors which affect demand and supply. As long as the economy is neither closed to trade or a larger exporter, fluctuations in global demand or supply should lead to exogenous variation in the price.[3] Therefore, an analysis of the relationship between the price and fisheries management tests the theoretical predictions, even though changes in the price do not necessarily reflect increases access to foreign markets.

Due to the limitations of the price variable as a measure for trade liberaliz-

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[3] The analysis shows that the negative relationship between the price and management pertains if closed economies and large exporters are excluded from the sample.

ation, our analysis also explores the relationship between the introduction of catch share programs and other proxies for trade openness. The data do not suggest that openness to trade, measured as the sum of exports and imports relative to domestic production of the respective fish species, is a significant factor in the decision to introduce catch share programs. However, the export value is significantly positively correlated with the introduction of catch share programs. Based on these results, it is not possible to conclude that trade is either good or bad for fisheries management.

A precise answer would be important for the sustainability of the world's oceans. According to Worm et al. (2006), about 27% of the world's fisheries were collapsed[4] by 2003 and the percentage of collapsed fisheries is increasing. Catch share programs have turned out to be successful instruments in avoiding fisheries collapse (Costello et al., 2008). Since nearly 40 percent of fisheries products are traded internationally (FAO, 2008), it is important to know whether trade hinders of fosters the introduction of catch share programs.

However, future research on trade and resource management should not be limited to fisheries. It would be interesting to investigate how trade affects the sustainable management of other renewable resources such as forests.

The effect of trade on renewable resources determines whether environmentalists' fears concerning adverse effects of trade on resources are justified or not. Copeland (2011) highlights that trade openness is not associated with overharvesting if property rights for the resource are in place. On the other hand. if trade does not affect resource management or if it leads to the collapse of resource management systems, environmentalists are right to worry about overharvesting when a country with poor property rights opens up to trade. But even in this case, trade restrictions are only a second-best policy instrument for resource management. Domestic regulations which internalize the externalities associated with open access are the ideal solution.

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[4] Worm et al. (2006) define a fishery as collapsed in year t if the catch in that year is less than 10 percent of the maximum catch since 1950.

Bibliography

Antweiler, W., Copeland, B., and Taylor, M. S. (2001). Is free trade good for the environment? *American Economic Review*, 91(4):877–908.

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

Asche, F. and Smith, M. (2009). *Trade and Fisheries: Key Issues for the World Trade Organization.* Available at www.wto.org/english/res_e/reser_e/ersd201003_e.pdf, accessed on 25/08/2014.

Baldwin, R. (1989). The political economy of trade policy. *The Journal of Economic Perspectives*, 3(4):119–135.

Barbier, E. B. and Burgess, J. C. (2001). The economics of tropical deforestation. *Journal of Economic Surveys*, 15(3):413–433.

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

Baum, C. F., Schaffer, M. E., and Stillman, S. (2002). IVREG2: Stata module for extended instrumental variables/2SLS and GMM estimation. Statistical Software Components, Boston College Department of Economics.

Bohn, H. and Deacon, R. T. (2000). Ownership risk, investment, and the use of natural resources. *American Economic Review*, 90(3):526–549.

Brander, J. A. and Taylor, M. S. (1997a). International trade and open-access renewable resources: The small open economy case. *Canadian Journal of Economics*, 30(3):526–552.

Brander, J. A. and Taylor, M. S. (1997b). International trade between consumer and conservationist countries. *Resource and Energy Economics*, 19(4):267–297.

Branstetter, L. G. and Feenstra, R. C. (2002). Trade and foreign direct investment in China: a political economy approach. *Journal of International Economics*, 58(2):335–358.

Brettell, A. (2013). A survey of environmental deterrence in China's evolving regulatory framework. In Ren, B. and Shou, H., editors, *Chinese environmental governance: Dynamics, challenges and prospects in a changing society*, chapter 2, pages 21–82. Palgrave Macmillan, Basingstoke.

Caves, R. E. (1976). Economic models of political choice: Canada's tariff structure. *Canadian Journal of Economics*, 9(2):278–300.

Chan, A. K. K. (2008). An overview of the VAT export refund rules in China. *Tax Notes International*, 49(3):159–164.

Chandra, P. and Long, C. (2013). VAT rebates and export performance in China: Firm-level evidence. *Journal of Public Economics*, 102:13–22.

Chao, C.-C., Chou, W., and Yu, E. S. (2001). Export Duty Rebates and Export Performance: Theory and China's Experience. *Journal of Comparative Economics*, 29(2):314–326.

Chao, C.-C., Yu, E. S., and Yu, W. (2006). China's import duty drawback and VAT rebate policies: A general equilibrium analysis. *China Economic Review*, 17(4):432–448.

Chen, B. and Feng, Y. (2000). Openness and trade policy in China: An industrial analysis. *China Economic Review*, 11:323–341.

Chen, C.-H., Mai, C.-C., and Yu, H.-C. (2006). The effect of export tax rebates on export performance: Theory and evidence from China. *China Economic Review*, 17(2):226–235.

Cheung, W. and Sumaila, U. (2015). Economic incentives and overfishing: a bioeconomic vulnerability index. *Marine Ecology Progress Series*, in press.

Chichilnisky, G. (1994). North-south trade and the global environment. *American Economic Review*, 84(4):851–874.

Cole, M. a., Elliott, R. J., and Wu, S. (2008). Industrial activity and the environment in China: An industry-level analysis. *China Economic Review*, 19(3):393–408.

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

Copeland, B. (1994). International trade and the environment: Policy reform in a polluted small open economy. *Journal of Environmental Economics and Management*, 26:44–65.

Copeland, B. (2011). Trade and the environment. In Bernhofen., D., Falvey, R., Greenaway, D., and Kreickemeier, U., editors, *Palgrave Handbook of International Trade*, chapter 15. Palgrave Macmillan, Basingstoke.

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

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

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

Corden, W. M. (1974). *Trade Policy and Economic Welfare.* Oxford University Press, Oxford.

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

Dasgupta, S., Laplante, B., Mamingi, N., and Wang, H. (2001). Inspections, pollution prices, and environmental performance: Evidence from China. *Ecological Economics*, 36(3):487–498.

Deacon, R. (1994). Deforestation and the Rule of Law in a Cross-Section of Countries. *Land Economics*, 70(4):414–430.

Dean, J. M. and Lovely, M. E. (2010). Trade growth, production fragmentation, and China's environment. In Feenstra, R. C. and Wei, S.-J., editors, *China's Growing Role in World Trade*, pages 429–469. University of Chicago Press, Chicago.

Dean, J. M., Lovely, M. E., and Wang, H. (2009). Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. *Journal of Development Economics*, 90(1):1–13.

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

Ederington, J. and Minier, J. (2003). Is environmental policy a secondary trade barrier? An empirical analysis. *Canadian Journal of Economics/Revue canadienne d'Economique*, 36(1):137–154.

Editorial Department of the Customs Import and Export Tariff of the People's Republic of China (2006). *Customs Import and Export Tariff of the People's Repulic of China.* Economic Daily Press, Beijing.

Editorial Department of the Customs Import and Export Tariff of the People's Republic of China (2007). *Import and Export Tariff of the People's Republic of China.* Economic Daily Press, Beijing.

Editorial Department of the Customs Import and Export Tariff of the People's Republic of China (2009). *Import and Export Tariff of the People's Republic of China.* Economic Daily Press, Beijing.

Ethier, W. J. (2011). The political economy of protection. In Bernhofen, D., Falvey, R., Greenaway, D., and Kreickemeier, U., editors, *Palgrave Handbook of International Trade*, chapter 10, pages 295–320. Palgrave Macmillan, Basingstoke.

Evenett, S. J., Fritz, J., and Jing, Y. C. (2012). Beyond dollar exchange-rate targeting: China's crisis-era export management regime. *Oxford Review of Economic Policy*, 28(2):284–300.

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

FAO (2008). *The state of world fisheries and aquaculture.* Food and Agricultural Organization of the United Nations, Rome.

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

Feenstra, R. and Hanson, G. (1999). The impact of outsourcing and high-technology capital on wages: estimates for the United States, 1979–1990. *The Quarterly Journal of Economics*, 114(3):907–940.

Feldstein, M. and Krugman, P. (1990). International trade effects of value-added taxation. In Razin, A. and Slemrod, J., editors, *Taxation in the Global Economy*, pages 263–282. University of Chicago Press, Chicago.

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

Ferreira, S. (2004). Deforestation, property rights, and international trade. *Land Economics*, 80(2):174–193.

Froese, R. and Pauly, D. (2015). *FishBase*. Available at www.fishbase.org, accessed on 19/12/2015.

Gang, C. (2009). *Politics of China's Environmental Protection: Problems and Progress*. World Scientific, Singapore, London.

Garred, J. (2014). Capturing the Value Chain: The Persistence of Trade Policy in China After WTO Accession. *mimeo*.

Gawande, K. and Krishna, P. (2003). The political economy of trade policy: Empirical approaches. In Choi, E. K. and Harrigan, J., editors, *Handbook of International Trade*, volume 1, pages 139–152. Blackwell, Oxford, UK, 1 edition.

Gourdon, J., Hering, L., Monjon, S., and Poncet, S. (2014). Export management and incomplete VAT rebates to exporters : the case of China. *FERDI Working Paper*, 117(December 2014).

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

Greenaway, D. (1980). Trade taxes as a source of government revenue: An international comparison. *Scottish Journal of Political Economy*, 27(2):179–183.

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

Grossman, G. and Helpman, E. (1994). Protection for sale. *American Economic Review*, 84(4):833–850.

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

Hummels, D., Ishii, J., and Yi, K.-M. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics*, 54(1):75–96.

Information Office of the State Council of the People's Republic of China (2008). *Communication on China's Policies and Action for Addressing Climate Change.* Available at www.ccchina.gov.cn/WebSite/CCChina/UpFile/File419.pdf, accessed on 05/01/2012.

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

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

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

Karapinar, B. (2011). China's export restriction policies: complying with 'WTO plus' or undermining multilateralism. *World Trade Review*, 10(03):389–408.

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

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

Markusen, J. (1975). International externalities and optimal tax structures. *Journal of International Economics*, 5:15–29.

Mas-Colell, A., Whinston, M. D., and Green, J. R. (1995). *Microeconomic Theory.* Oxford University Press, New York, Oxford.

Mathiesen, K. (2014). What does the biggest free trade deal in history mean for the environment?

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

Miller, R. E. and Blair, P. D. (1985). *Input-output analysis: Foundations and extensions.* Prentice-Hall, Englewood Cliffs, N.J.

Milner, C. and Xu, F. (2009). On the Pollution Content of China's Trade: Clearing the Air? *China and the World Economy Research Paper Series*, 2009/19.

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

NDRC (2007). *China's National Climate Change Programme.* Available at www.ccchina.gov.cn/WebSite/CCChina/UpFile/File188.pdf, accessed on 08/03/2013.

Neary, P. and Ruane, F. (1998). International capital mobility, shadow prices, and the cost of protection. *International Economic Review*, 29(4):571–585.

NPC (1989). Zhonghua Renmin Gongheguo Huanjing Baohu Fa [Environmetal Protection Law of the People's Repulic of China].

OECD (2005). *China in the Global Economy: Governance in China.* OECD Publishing, Paris.

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

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

Piermartini, R. (2004). *The Role of Export Taxes in the Field of Primary Commodities.* WTO, Geneva, Switzerland.

Ray, E. (1981a). Tariff and nontariff barriers to trade in the United States and abroad. *The Review of Economics and Statistics*, 63(2):161–168.

Ray, E. (1981b). The determinants of tariff and nontariff trade restrictions in the United States. *The Journal of Political Economy*, 89(1):105–121.

Ren, B. and Shou, H. (2013). Introduction: Dynamics, challenges, and opportunities in making a green China. In Ren, B. and Shou, H., editors, *Chinese environmental governance: Dynamics, challenges and prospects in a changing society*, chapter 1, pages 1–20. Palgrave Macmillan, Basingstoke.

Roheim, C. A. (2005). Seafood: Trade liberalization and impacts on sustainability. In Aksoy, M. A. and Beghin, J. C., editors, *Global Agricultural Trade and Developing Countries*, pages 295–317. World Bank, Washington D.C.

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

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

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

Stalley, P. (2010). *Foreign firms, investment, and environmental regulation in the People's Republic of China.* Stanford University Press, Stanford, California.

StataCorp. (2013). *Stata 13 reference manual: ipolate — Linearly interpolate (extrapolate) values.* Available at http://www.stata.com/manuals13/dipolate.pdf, accessed on 16/05/2015.

State Council of People's Republic of China (2006). *China National Environmental Protection Plan in the Eleventh Five Years (2006-2010).* Available at http://english.mep.gov.cn/down_load/Documents/200803/P020080306440313293094.pdf, accessed on 09/-3/2013.

Steckel, J. C., Jakob, M., Marschinski, R., and Luderer, G. (2011). From carbonization to decarbonization?-Past trends and future scenarios for China's CO2 emissions. *Energy Policy*, 39(6):3443–3455.

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

Swartz, W., Sumaila, R., and Watson, R. (2012). Global Ex-vessel Fish Price Database Revisited: A New Approach for Estimating 'Missing' Prices. *Environmental and Resource Economics*, 56(4):467–480.

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

Taylor, M. (2011). Buffalo Hunt: International Trade and the Virtual Extinction of the North American Bison. *American Economic Review*, 101(December 2011):3162–3195.

Trefler, D. (1993). Trade liberalization and the theory of endogenous protection: an econometric study of US import policy. *Journal of Political Economy*, 101(1):138–160.

Turunen-Red, A. H. and Woodland, A. D. (2002). Unilateral Reforms of Trade and Environmental Policy. In Woodland, A. D., editor, *Economic Theory and International Trade: Essays in Honour of Murray C. Kemp*. Edward Elgar Publishing, Cheltenham.

Turunen-Red, A. H. and Woodland, A. D. (2004). Multilateral Reforms of Trade and Environmental Policy. *Review of International Economics*, 12(3):321–336.

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

Vlassis, N. (2013). The Welfare Consequences of Pollution-Tax Harmonization. *Environmental and Resource Economics*, 56(2):227–238.

Wang, H., Mamingi, N., Laplante, B., and Dasgupta, S. (2003). Incomplete enforcement of pollution regulation: Bargaining power of Chinese factories. *Environmental and Resource Economics*, 24:245–262.

Wang, H. and Wheeler, D. (2005). Financial incentives and endogenous enforcement in China's pollution levy system. *Journal of Environmental Economics and Management*, 49(1):174–196.

Wang, X., Li, J., and Zhang, Y. (2010). Can export tax be genuine climate policy? An analysis on China's export tax and export VAT refund rebate policies. *Idées pour le débat Working Paper*, No 08/2010.

Wang, X. and Xie, S. (2010). Zhongguo chukou tuishui zhengce de juece he xingcheng jizhi. *Jinji Yanjiu*, 10:101–114.

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

WGI (2012). *Worldwide Governance Indicators.* Available at http://info.worldbank.org/governance/wgi/index.aspx#doc, accessed on 31/01/2016.

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

Wooldridge, J. M. (2009). *Introductory Econometrics: A Modern Approach.* South-Western/Cengage, London, 4th intern edition.

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel Data.* MIT Press, Cambridge, Masschusetts, London, 2nd ed. edition.

World Bank (2007). *Cost of pollution in China: Economic estimates of physical damages.* World Bank, Washington D.C., conference edition.

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

WTO (2008). Trade Policy Review: Report by the Secretariat, China, Revision. *WTO Trade Policy Reviews*, WT/TPR/S/1.

WTO (2013a). *China — Measures Related to the Exportation of Various Raw Materials.* Available at http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds394_e.htm, accessed on 09/03/2013.

WTO (2013b). *WTO rules and environmental policies: GATT exceptions.* Available at http://www.wto.org/english/tratop_e/envir_e/envt_rules_exceptions_e.htm, accessed on 09/03/2013.

WTO (2014). *China — Measures Related to the Exportation of Rare Earths, Tungsten and Molybdenum.* Available at http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds431_e.htm, accessed on 20/12/2014.

Xie, J., Liebenthal, A., Warford, J. J., Dixon, J. a., Wang, M., Gao, S., Wang, S., Jiang, Y., and Ma, Z. (2009). *Addressing China's Water Scarcity: Recommendations for Selected Water Resource Management Issues.* The World Bank, Washington D.C.

Yue, C. and Hua, P. (2002). Does comparative advantage explains export patterns in China? *China Economic Review*, 13(2-3):276–296.