Essays on Environmental Regulation, Management and Conflict

Eric Sjöberg
To Rebecka.
For endless love and support.
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Chapter 1

Introduction

This thesis consists of three self-contained chapters. The chapters differ in the issues that are studied and the methods that are used, but share the common theme that they address different environmental problems. In chapter 1, I evaluate whether there are systematic differences in enforcement of the Swedish environmental code across Swedish municipalities. In chapter 2, I study how size affects the price of fish and discuss potential implications for regulation. In chapter 3, I construct a settlement model, interpreted as a model of an environmental conflict, to study how asymmetric information affects the cost of engaging in a conflict and the implications for settlement.

To address these environmental issues, I have chosen to use both theoretical and empirical tools. Moreover, besides basing my research on the environmental and agricultural economics literature, I rely on other fields of economics. The first and third chapters have strong political economy components. I believe environmental economics and political economy to be a fruitful combination as many of the environmental problems we have today are due to coordination failures and need to be addressed on the political level.

Thus, I apply different methods and use different fields of economics to study environmental problems. Moreover, having been a part of two different multidisciplinary research teams has given me opportunities to better understand the issues that I study. I think that inter- or transdisciplinary research is a productive approach to environmental issues (Baumgärtner et. al. 2008). As all other research, economic research is produced in a context, and having been able to discuss my research in such an interdisciplinary
Introduction

environment has given me many new and interesting perspectives. Below, I provide a summary of each paper of my thesis.

**Paper 1: The political economy of environmental regulatory compliance**

In my first paper, I use the number of environmental fines issued in a municipality to study if local politicians affect enforcement of national environmental legislation. This may be problematic due to the fact that the cost of lenient enforcement is shared also by surrounding municipalities while the benefits, better relation with local firms (Boskovic 2010), are private. If local politicians choose their own enforcement stringency, this might render national policies inefficient; see Fredriksson et.al (2010) for a related theoretical model.

This paper also relates to the political economy literature that explains how parties and politicians personal preferences may shape policy outcomes (Persson Tabellini 2007, chapter 5). I show empirically that even for a given policy, politicians can still affect the outcome through the enforcement process.

There are theories that have been suggested to show that there is a trade-off between strictness in environmental enforcement and business friendliness, (Sigman 2004). I assume that the Green Party values this tradeoff differently than other parties and use a difference in differences approach to see if municipalities where the Green party is a member of the ruling coalition issue more fines.

In Sweden, environmental enforcement takes place at the municipality level and is conducted by the local environmental offices. Environmental inspectors work with both desktop and on-site inspections. Violations of the environmental code may result in fining. The environmental offices are led by local politicians that are members of an environmental board. The environmental board sets the budget and guidelines for the environmental office and the board members may also interact with officials in board meetings.

I find that Green Party municipalities issue more fines on average than other municipalities. The effect is driven by municipalities where the Green Party joins the ruling political coalition. The findings are robust over a range of different specifications, but with varying precision. I also use an instrumental variable approach where Green Party inclusion in the ruling
political coalition is instrumented by the absence of local party representation in the municipality which I assume to be as good as random. This robustness check generates qualitatively similar results.

I investigate different potential mechanisms. I find no signs that Green Party municipalities behave differently in terms of financing. Neither do I find evidence of that Green Party municipalities would conduct more inspections or review a larger share of the environmental reports that firms submit. However, I find plenty of anecdotal evidence of politicians exerting undue influence on the workers of the environmental offices. If Green Party politicians are less prone to exert this influence, this could be the working mechanism.

Paper 2: Pricing on the fish market - Does size matter?

In my second paper, I study the relationship between fish size and fish price and discuss the implications for regulation. Fish of different size sell for different prices on the market. I utilize that some fish species are divided and sold in different weight categories on the Swedish fish market, to study how changes in the size composition of the catch affect market prices.

Changes in the size composition of the catch can be due to several reasons. Both high grading and growth overfishing, the practice to discard less valuable fish and target fish of specific sizes, respectively, have the possibility to alter the size composition. There is also some evidence that a changing climate affects fish size (Casini et.al 2010). Moreover, recent theoretical work implies that size is an important factor to take into account when formulating regulation (Diekert 2012). New models that take the size structure of the fish stock into account, generate important implications for regulation compared to traditional models where the stock is treated as homogeneous. For example, one of the conclusions of this recent work is that regulation on number of fish rather than weight can be optimal. However, age-structured models usually assume prices to be constant. I show that prices are highly endogenous to the size composition of the fish stock which should be incorporated in future age-structured models.

To study the relationship between fish size and fish price, I test the economic and statistical assumptions of several different inverse demand models to select the most appropriate one for estimation. I use the model to estimate quantity and scale flexibilities, which are inverse demand counterparts
to price and income elasticities, respectively. Quantity flexibilities measures the percentage change in the price of size category $i$ when quantity increases with 1% in category $j$. Scale flexibilities measure the percentage change in price for a proportional increase of 1% in all size categories.

I find that the relationship between fish size and fish price is highly dependent on the species. For most species, large fish are more valuable than smaller fish. However, it is not in general the case that an increase in larger weight categories has a larger impact on the prices than an increase in smaller categories. The size of the quantity flexibilities vary, but in general own quantity flexibilities are larger than cross quantity flexibilities. Most quantity flexibilities lie in a range between -0.1 and -0.4 implying that an increase in the quantity of a weight category with 1% decreases prices with between 0.1 and 0.4%. Scale flexibilities are in general close to -1 implying homothetic goods.

The results imply that prices are highly endogenous to the size structure of the catch. Theoretical models that include size structured fish stock are becoming increasingly more popular and suggest new ways on how to optimally manage fish stocks, e.g. regulating on numbers of fish. These new regulation methods would, if implemented, alter the size composition of the catch. An important aspect that should be included in future work is the resulting changes in equilibrium prices, which often are assumed to be constant in the theoretical models. The flexibilities estimated in this paper could be used as a starting point to shed some light on how prices can change due to new size structures of the catch, whether it is due to new regulation, global warming, growth overfishing or high grading.

**Paper 3: Settlement under the threat of conflict - The cost of asymmetric information**

The third paper of my thesis is a model over litigation and settlement. Two players disagree over how a good should be divided. The two players differ in their valuation of the good. One player’s valuation is known (the uninformed player) while the other player’s valuation is known only to that player (the informed player).

I model settlement through a two-stage game. In the first stage, a contract that specifies a division of the good is presented to both parties. Both players can either accept or reject the contract. If both parties accept the
contract, the good is divided accordingly and the game ends. If either player rejects the contract, they enter the second stage. In the second stage, the players need to invest in costly effort in order to obtain the good in a contest, similar to lobbying or a court procedure. The contest is based on the model presented in Hurley and Shogren (1998).

Both players would ideally like to avoid the contest and divide the good peacefully. My two main research questions are, how does one-sided asymmetric information affects the settlement decision through affecting the expected contest outcome, and, is it always possible to specify a peaceful division of the good that both players prefer instead of going into a contest?

Not surprisingly, I find that a contest that implies high rent dissipation makes a peaceful contract more feasible. New information, in terms of changes in the expected mean and variance of the players’ relative valuation, can make a peaceful contract both more and less likely. A higher variance always makes the informed player better off and the uninformed player worse off in a contest. This means that they are more and less likely to agree to a peaceful contract respectively. The net effect depends on the full parameterization of the model. There is only one type of new information that always makes a peaceful contract more feasible. This happens if the uninformed player believes herself to have a higher probability to win the contest (contest favorite) while the mean of their relative valuation decreases, indicating that the informed player has on average a larger valuation. This would make both player worse of in the contest. The uninformed player invests more resources into the contest since she now believes that she faces a stronger player, while the informed player now faces a tougher opponent.

One-sided asymmetric information contests are often used to study environmental conflicts, such as land use conflicts between extraction industries and the general public. I discuss the findings of this model in terms of using side payments as a mean to mitigate land use conflicts in the Arctic. Side payments are used, or have the potential to be used, in several different instances, such as between petroleum companies and fishermen in Lofoten Norway, home-owners and a large mining company in Kiruna Sweden, and reindeer herders and the Russian gas industry on the Yamal peninsula. Current compensation schemes typically focus on compensation for economic damages. New valuation studies that also include valuations of non-market goods, such as eco-system services or pristine nature, would according to my
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suggested model increase compensations and also the feasibility of peaceful solutions.

References


Chapter 2

The political economy of environmental regulatory compliance*

Abstract

A potential problem with local enforcement of national legislation is the varying degrees of implementation that the decentralized structure may create. To study the severity of this problem, induced by the mismatch of local and national incentives, I look at the enforcement of the Swedish Environmental Code which is a national legislation enforced at the local level. I measure enforcement in terms of environmental fines issued in each of Sweden’s 290 municipalities. The main political tradeoff in enforcement is between business and environmental friendliness. I utilize the fact that the Green Party values this tradeoff differently from other parties. Using both a difference-in-differences approach and IV, I conclude that municipalities with the Green Party in the ruling coalition issue more environmental fines than other municipalities. This is problematic from an efficiency and equality perspective. The result suggests that politicians do not only affect policy, but also that for a given policy, they can affect the outcome through implementation and enforcement.

Keywords: Environmental regulation, Decentralization, Law enforcement

JEL-codes: K42, K32, Q01

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2.1 Introduction

Ever since Paul Samuelson’s seminal 1954 article "The Pure Theory of Public Expenditure", economists have been interested in the optimal provision of a public good. Aspects of this problem include the pros and cons of centralized versus decentralized provision in a multilevel political system; see e.g., Williams (1966), Tullock (1969) or Besley and Coate (2003). While there have been many theoretical studies on this issue, the empirical evidence is more scarce. In this study, I utilize characteristics of Swedish environmental law enforcement to study some potential implications of decentralized provision of a public good.\(^1\)

Both theory and practice can be used to argue for either centralized or decentralized provision of a public good. From a theoretical point of view, Oates’s decentralization theorem (Oates, 1972) essentially states that without externalities, local provision of a public good is optimal while introducing externalities makes the optimal provision level unclear. Regarding enforcement of environmental regulations, some potential benefits of local enforcement can be noted from an applied point of view. Local governments may have information advantages. Moreover, environmental aspects are often closely related to other local issues, such as urban planning. But local enforcement of environmental regulations, or the lack thereof, might also produce negative externalities. Lenient enforcement can help the municipality appear business friendly (DS 2006:67 p. 18) and attract firms, while the costs of a bad environmental situation are shared also by the surrounding municipalities. Fredriksson et al. (2010) show in a theoretical model that this set up leads to a home bias where local politicians may favor their local district and impose sub-optimal regulations.\(^2\) The authors conclude their paper by requesting future empirical studies to “be on the lookout for [home] bias as an environmental policy determinant”. It is my aim to start filling this gap in the literature.

I want to test if there are any systematic differences across local governments in the application of environmental laws. Such differences are mainly

\(^1\)Traditionally, law enforcement has also been classified as a quasi-public good since excludability is possible. This distinction is, however, not important for my study.

\(^2\)Fredriksson et al. denote this majority bias since the results are derived in a majority election system where politicians set environmental taxes on industries depending on how pollution affects local (home) districts that are crucial for elections. To avoid misunderstandings referring to the majorities in my paper, I use the term home bias.
2.1. **INTRODUCTION**

problematic for two reasons: legal security and efficiency.\(^3\) If firms face different risks of being penalized when they are caught in violation of national legislation depending on the local government, this is a sign of inequality before the law. Moreover, local governments that make their own interpretation of national legislation can cause inefficiencies since their incentives to take externalities into account when deciding on optimal enforcement may differ from those of a national policy maker.

As a proxy for environmental enforcement, I use the normalized number of environmental sanction charges (fines hereafter) issued across Swedish municipalities. The fines are based on the Swedish Environmental Code which is a national legislation and thus applies to all municipalities. There is room for local variation in enforcement in my study since ever since the introduction of the Swedish Environmental Code in 1999, the enforcement of environmental regulations has to a large extent been provided at a local government (municipality) level. However, since the issuing of fines is based on national legislation, everything else equal, no significant systematic differences ought to be found.

To detect signs of a systematic home bias, I focus on the Green Party since it can be assumed to have a different tradeoff between business and environmental friendliness as compared to other parties. The existence of a varying enforcement of environmental regulations can then be motivated by the political economics literature on partisan politicians, see e.g. chapter 5 in Persson and Tabellini (2000). In this literature, for a given set of electorate preferences, parties’ and politicians’ private preferences influence policy, or in my case, implementation of policy. I study the potential effect of the Green Party being part of the ruling political coalition on the number of environmental fines issued across municipalities. The effect is estimated to be positive and is consistent across different models and identification strategies. The precision of the estimates varies, however.

To overcome the inherent difficulties in estimating effects of endogenously elected parties, I apply two identification strategies.\(^4\) My main strategy is a difference-in-difference approach where the treatment group is defined to be the municipalities where the Green Party was included in the ruling

\(^3\)The seriousness of these problems also depends on the interaction between the impact of the externalities, how local preferences differ and to what extent national legislation allows for differences in enforcement.

\(^4\)See, for example, Besley and Case (2000) for a discussion of these problems.
coalition during any or both term periods 2003-2006 and 2007-2010. The second identification strategy applied is an instrumental variable approach. The absence of other alternatives (local parties) with which to form a coalition for either the left or the right wing will be used as an instrument for Green Party inclusion in the ruling coalition in municipalities with an unclear election outcome. The IV estimates are less precise but indicate that OLS underestimates the effect. The data is gathered in the Swedish political system but the setting is applicable also in other countries such as Germany and the U.S., or in other areas of public policy such as animal welfare, food inspections or emission control.

Different potential mechanisms through which political parties can affect enforcement are discussed in the paper. Utilizing the fact that some municipalities (voluntarily) report the number of inspections and the share of reviewed environmental reports, and that the net cost of the environmental board varies, I evaluate these proposed mechanisms. There is also anecdotal evidence of direct political pressure on local environmental offices. In different surveys, between one quarter and one third of the environmental officers have stated that political influence obstructs an efficient enforcement of the environmental code (Jacobsson and Källmén, 2012 and DS 2000:67). For example, in one municipality in southern Sweden, the politicians refused to affirm two fines issued by environmental inspectors and motivated this by writing that “the electorate must demand [of the politicians] to do their utmost to make [the municipality] not look business unfriendly” (Ds 2000:67 p.160f). More examples are provided in the result section.

Few empirical studies have been conducted on the political economy of environmental regulation; see Dijkstra and Fredriksson (2010) for a brief survey. Boskovic (2010) develops a structural model where states face a tradeoff between air quality and business friendliness. Using U.S. data, he finds that states where enforcement is decentralized also increase their pollution levels and attract more firms. This is a very interesting finding. I cannot investigate this relationship with Swedish data since there is no exogenous change in decentralization of environmental enforcement. What distinguishes my paper from Boskovic (2010) is my focus on specific political parties and their influence on the enforcement. Moreover, I study the instruments of environmental enforcement rather than the direct environmental effect.

The same differences can be found between my paper and Sigman (2004).
2.2. INSTITUTIONAL BACKGROUND

Sigman investigates the effect of decentralization on water quality in streams that run across states. Her findings show that decentralization does not have any effect on the water quality within a state. However, the water quality in downstream states is negatively affected by upstream states gaining control over environmental regulation and enforcement implying free riding.

My paper also relates to the political economy literature on the relationship between parties’ and politicians’ preferences, and public policy, see e.g. Besley and Coate (1997), Chattopadhyay and Duflo (2004), Folke (2010), Persson et al. (2007), or Svaleryd (2009). In this strand of literature, parties and politicians shape public policy not only by representing the preferences of the electorate, e.g. through the median voter, but also by expressing private preferences. The results of my paper imply that even for a given policy that is a true representation of electorate preferences, parties or politicians may still determine the outcome through enforcement and practical implementation.

The rest of the paper is organized as follows. In section 2.2, the institutional background to environmental monitoring in Sweden and the Swedish political scene are presented. The data used in this paper is described in section 2.3. In section 2.4, the problems with estimating party effects in a proportional election system are discussed. Both the difference-in-differences and the IV-strategies are thoroughly described here. The main results and robustness checks are presented in section 2.5 where some potential mechanisms are also investigated. Section 2.6 concludes the paper with some final thoughts on decentralized enforcement of environmental regulation.

2.2 Institutional background

Enforcement of the Swedish environmental code

The new Swedish Environmental Code was adopted in 1998. It came into force at the beginning of 1999. Sweden consists of 290 municipalities which are nested into 21 counties and the reform further decentralized the monitoring of firms’ environmental performance to these municipalities and counties. For the potentially most hazardous facilities, monitoring is still managed at

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5 The facts in this section are gathered from the Swedish Environmental Code (1998:808), The Ordinance on Environmental Penalties (1998:950) and Regulation 1998:899.
The political economy of environmental regulatory compliance

a national level by the Swedish Chemical Agency and the Swedish Board of Agriculture. Environmental enforcement is thus performed at three nested levels (national, county and municipality), where the more hazardous objects are managed at higher levels. The enforcement at the municipality level quantitatively constitutes the vast majority of all monitoring. For example, of the total number of fines in 2009, 89% were issued at the municipality level while the rest were evenly distributed at the two other levels.

The focus of this study is on fines resulting from enforcement at the municipality level. It is the environmental protection office in each municipality that performs the day to day enforcement. The local office is complemented by an environmental board consisting of local politicians who meet roughly once a month to lead the work of the office.\(^6\)

All firms are possibly subject to environmental inspections. The most hazardous types of businesses, as regulated in the environmental code, are classified into four different categories A, B, C and U. In 2004, the distribution of firms in the different categories was approximately 500 A, 5,500 B and 17,500 C (SEPA 2004 p. 75). Among other things, the classification represents and determines the environmental hazard level, permits or licenses needed for the type of business and the frequency of inspections. The most environmentally hazardous firms are classified as an A. Municipalities are usually responsible for monitoring firms in categories B-U and non-classified firms.\(^7\) The frequency of inspections can be anything from several times a year to practically never. Inspections can be both scheduled and unscheduled and are performed by inspectors from the environmental protection office of the municipality. If any faults are found, they are reported by the inspector and the firm can eventually be fined.

The fines considered in this paper are issued by the local environmental offices in each municipality. They are to a great extent the result of firms not having the right permission for their business, firms being late with their environmental reports or the consequence of failing parts of the inspection. The fines can be issued directly by the environmental office.\(^8\)

\(^6\)In a few instances, more commonly in recent years, two or three small municipalities share environmental protection office and/or environmental board.

\(^7\)The distribution of firms over categories gives further evidence that municipalities manage the major part of the enforcement.

\(^8\)For more serious offenses, violations may lead to prosecutions in court.
Fines range between 1,000 and 1,000,000 SEK.\(^9\) The firms also pay a fee for the inspections which in theory should make the inspections carry their own costs. The fines, on the other hand, do not remain in the municipality but go straight into the national treasury. Thus, there is no direct monetary incentive for municipalities to have a high level of fines.

Fines themselves are not the driving force behind environmental progress. But they are an integral part of the monitoring process and without them, any legislation runs the risk of being ineffective. The fines are intended to be issued with “quickness, simplicity and clarity” (SOU 2004:37) in order to increase acceptance at the firm level. It is not clear whether a low level of fines is an unambiguously positive indicator of inspection or environmental quality. Few fines could mean either of two things. It could be the case that the environmental enforcement works perfectly so that firms comply with the Environmental Code. But it could also be the case that the enforcement works poorly so that very few violations are discovered. It is important to note that I do not use the number of fines to determine the optimal level of enforcement but as a proxy to detect systematic differences in enforcement. In general, a measure of efficient environmental enforcement is not available. Other proposed measures, such as the number of inspections, man months per year or the size of the budget suffer from the same disadvantages as fines. A battery of indicators would usually be suggested (IMPEL 2010) if one were to evaluate the efficiency of the monitoring in order to get a more complex picture of the process. In Sweden, unfortunately, data on the number of inspections, complaints dealt with etc. is not collected at the national level.\(^10\)

Some concern can also be raised about whether the number of issued fines is a good proxy for enforcement of the environmental code. As is shown in the data and result section, the fines are in general quite few and the average fine is not very large. However, in an ongoing project regarding efficient environmental inspections and enforcement, a cross-section survey was conducted where data on the number of indictments and injunctions issued across Swedish municipalities was also collected (Jacobsson and Källmén 2012). The result indicated that the number of fines correlates strongly and

\(^9\) Approximately €115 and €115,000.

\(^10\) Some municipalities, however, report them in their annual reviews which I utilize in the result section to evaluate some proposed mechanisms.
positively with these more severe (indictments) and common (injunctions) measurements of environmental enforcement.

**Parties and politics in Sweden**\(^{11}\)

Elections are held the second Sunday in September every fourth year. Aside from the occasional vote on a local issue, the electorate cast their vote in three different elections: national, county council and municipal. The focus of this paper is on the two term periods 2003-2006 and 2007-2010.

Historically, even though several parties have received substantial vote shares, Sweden has been classified as a bipartisan system; see e.g., Petterson-Lidbom (2008). However, this picture has changed during the early 21st century. In the last two terms, eight parties have been represented in parliament and in a substantial share of the Swedish municipalities. The parties are the Center Party (C), the Christian Democrats (KD), the Moderates (M), the Green Party (GP), the Left Party (V), the Liberals (FP), the Social Democrats (S) and the Swedish Democrats (SD).\(^{12}\)

There are two distinct blocks in Swedish politics, here denoted left (L) and right (R) wing. The left wing consists of V and S. The right wing consists of C, FP, KD and M. At the national level, there are two more parties with substantial representation, the Green Party and the right-wing populist Swedish Democrats. The Green Party often cooperates with the left wing in national elections while at the municipality level, there is substantial variation across municipalities with respect to which block the Green Party cooperates with, even from term to term. In the two most recent elections, the Swedish Democrats also gained seats in many municipalities but they have yet to be included in a ruling majority. In municipality elections, it is also common to see local parties (LP) represented only in a single municipality or small region. Local parties typically focus on a small number of specific local issues such as splitting a municipality or a stronger emphasis on local issues.

Thus, there is potential for variation in political majorities. Given the election outcome, there is potential for the following outcomes, L, L + GP, L + LP, L + GP + LP, R, R + GP, R + LP, R + GP + LP, L + R, L + R

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\(^{11}\)The political scene in Sweden has been dealt with extensively in earlier papers in economics and even more so in political science; see e.g., Bäck (2003) and Folke (2010).

\(^{12}\)The acronyms come from their Swedish names except for the Green Party.
+ GP, L + R + LP, L + R + GP + LP. Theoretically, more outcomes are possible but none of the Green Party, local parties or the Swedish Democrats have gained large enough vote shares to form a combined or own majority. For more on coalition formation in Sweden, see Bäck (2003).

2.3 Data

The data on fines from environmental inspections was obtained from the Swedish Environmental Protection Agency. It is a complete dataset covering the years 2003-2009. Each original observation contains information on the firm that received the fine, the amount, date, and location (municipality). Data on ruling coalitions was not as easily obtained. Statistics Sweden (SCB) has data on the majorities of almost all municipalities for both the 2003-2006 and 2007-2010 term periods. For the 2007-2010 term, the data was supplemented by information from the Swedish Association of Local Authorities and Regions. Thus, I have been able to double check the information from SCB for one of the term periods and they overlap very well. Any inconsistencies were primarily solved by information from local newspapers or protocols from meetings. If any doubt still existed, I let the information from SCB override the other information. In the end, less than 3.3% of the observations could not be assigned a political majority due to missing data.14

All types of ruling coalitions listed in section 2.2 have at some point been formed during the last two term periods. Table 2.1 shows the frequencies of the different coalition types.

Pure left- or right-wing coalitions have been the two most common ruling coalitions. There have been more pure right-wing than left-wing coalitions. Local parties are more likely to be found in right- than left-wing coalitions and the Green Party is more likely to be found in left- than right-wing coalitions.15

13SD has been excluded since no political parties are willing to cooperate with them. See the description for frequencies.
14Most of the missing observations are due to jumping majorities.
15For the identification strategy, it is crucial that municipalities with and without local party representation in the council (not in the majority) do not systematically differ prior to the election. This is further discussed in the model section. It seems that local parties cooperate with right-wing parties to a larger extent. This would be troublesome if left-wing coalitions differ from right-wing coalitions in the effect on fines. However, figure 2.2 shows that pure left- and right-wing coalitions are similar in levels of fines. Neither do
Table 2.1: Frequencies of coalitions

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<td>R</td>
<td>165</td>
</tr>
<tr>
<td>R GP</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td><strong>Total 561</strong></td>
</tr>
</tbody>
</table>

*L consists of S and V. R consists of C, FP, KD and M.*

Table 2.2: Descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fines</td>
<td>3.17</td>
<td>12.29</td>
<td>0</td>
<td>401</td>
</tr>
<tr>
<td>Firms</td>
<td>3,429</td>
<td>7,652</td>
<td>363</td>
<td>126,883</td>
</tr>
<tr>
<td>Population</td>
<td>31,491</td>
<td>60,844</td>
<td>2,500</td>
<td>829,417</td>
</tr>
<tr>
<td>Average age</td>
<td>42.36</td>
<td>2.38</td>
<td>36.1</td>
<td>48.5</td>
</tr>
<tr>
<td>Municipal workers %</td>
<td>9.56</td>
<td>1.79</td>
<td>3.56</td>
<td>15.20</td>
</tr>
<tr>
<td>Only elementary school %</td>
<td>11.67</td>
<td>1.55</td>
<td>6.10</td>
<td>16.12</td>
</tr>
<tr>
<td>Postgraduates %</td>
<td>0.31</td>
<td>0.45</td>
<td>0</td>
<td>4.2</td>
</tr>
<tr>
<td>Firm share %, agriculture</td>
<td>28.76</td>
<td>14.47</td>
<td>1.20</td>
<td>62.01</td>
</tr>
<tr>
<td>Firm share %, manufacturing</td>
<td>6.71</td>
<td>1.92</td>
<td>2.31</td>
<td>22.69</td>
</tr>
<tr>
<td>Firm share %, construction</td>
<td>7.78</td>
<td>2.69</td>
<td>2.89</td>
<td>20.02</td>
</tr>
<tr>
<td>Firm share %, retail</td>
<td>12.4</td>
<td>3.09</td>
<td>4.11</td>
<td>24.94</td>
</tr>
<tr>
<td>Net cost of Env board, millions</td>
<td>5.35</td>
<td>10.88</td>
<td>-7</td>
<td>109</td>
</tr>
<tr>
<td>Number of inspections</td>
<td>143</td>
<td>193</td>
<td>0</td>
<td>950</td>
</tr>
<tr>
<td>Environmental reports reviewed %</td>
<td>53</td>
<td>40</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

All municipality and political covariates used in the model and result sections were also retrieved from SCB.\textsuperscript{16} Data on environmental attitudes in municipalities was collected from Riks-SOM, a survey made at polling stations during the 2006 election (Holmberg et al., 2006). Data on the number of inspections and the net cost of the municipality board was gathered from the municipalities’ annual reviews. Data on the share of environmental reports being reviewed by the environmental office in each municipality was collected from the Swedish Environmental Reporting Portal.\textsuperscript{17} Table 2.2 shows descriptive statistics. I control for population size and the number of firms to see if changes in these variables affect the number of fines. Changes right- or left-wing dummies show up significantly in the regressions.

\textsuperscript{16}The data on industrial structure was financed by the Swedish Environmental Protection Agency (SEPA) through the project Effektiv miljötillsyn, see http://www.effektivmiljotillsyn.se/ for further information.

\textsuperscript{17}https://smp2.naturvardsverket.se
2.4. **THE MODEL**

in the average age and education level are also controlled for as these variables might be proxies for certain municipality types. I also control for the number of workers employed by the municipality to see if there was a large expansion or contraction of the public sector in Green Party municipalities at the time of the election. Finally, I also control for the industrial structure of the municipality as this is likely to affect the work of the environmental office.

### 2.4 The Model

**Estimating party effects in a proportional election system**

First, I would like to discuss what theory predicts would happen to the number of fines if the Green Party were to be included in the ruling coalition. If we assume that the industrial structure remains the same and a constant share of the firms break the law, the number of fines should not change. This is due to the law being the same in all municipalities. If, on the other hand, firms start being more careful due to a higher risk of getting caught, we would see a *decrease* in fines with the Green Party in the ruling coalition, given that there is no party effect. There are, however, practical reasons for why the number of fines might change and why we might see an increase in the number of fines.

As discussed in the introduction, lenient enforcement can be used strategically by a municipality. This has been discussed as a potential problem of decentralized enforcement in Sweden (see e.g., DS 2000:67) and also in the US (Boskovic 2011). Any possible competitive advantages should be contrasted to the possible negative consequences of lowering the standards of environmental enforcement. If the Green Party values this tradeoff differently, which is likely, the number of fines might increase. This is analogous to the political economy literature on partisan politicians, see e.g. chapter 5 in Persson and Tabellini (2000), where parties’ and politicians’ preferences affect policy choice. The difference is that in my setting, the policy is given but parties and politicians can still affect the outcome through implementation and enforcement.

Potential mechanisms behind why the amount of fines increases are for example that the Green Party might assign higher budget shares to the environmental office. They can change the office’s priorities. But there is also
The political economy of environmental regulatory compliance

plenty of anecdotal evidence of political pressure on the environmental office to go easy on firms, as will be further exemplified in the paper. For example, there have been instances in Sweden where politicians on the environmental board have been convicted of professional misconduct and fined for stopping fines issued by the environmental office (SOU 2004:100 p.138). There are plenty of potential mechanisms and I will make an attempt to examine some of them in the result section.

It is difficult to causally link a political party to an outcome variable in a proportional election system (Imbeau et al., 2001). In an experimental setting, I would like to randomly assign the Green Party to the ruling political coalition in different municipalities and then look at how the number of fines varies. This is not possible since the ruling coalition is not a random variable but an outcome of voter preferences. Estimating a regression where the number of fines is dependent on a dummy variable indicating whether or not the Green Party is included in the political majority is likely to suffer from severe omitted variable bias. The Green Party is more likely to be included in the ruling coalition if it has a high vote share. Municipalities where the Green Party has a high vote share can have certain traits which might also correlate with the behavior of the firms, environmental inspectors etc. There are different strategies to overcome the problem of the non-random assignment of ruling political coalitions. Before further elaborating on the strategy applied in this paper, I will make a quick review of some of the earlier methods applied and also motivate why these methods will not be used in this paper.

A commonly used method to identify effects of endogenously elected parties is the regression discontinuity design, see Lee and Lemieux (2010). The idea is to look at and compare municipalities with election outcomes where the winning coalition is close to the 50% threshold. Petterson-Lidbom (2008) argues that Sweden can be classified as a two-party system and estimates the causal effect of a left-versus right-wing majority on a number of outcomes. For election outcomes close to the 50% threshold, it can then be argued that the political majority is as good as randomly assigned. It is assumed that the counterfactual outcome with a vote share of less than 50% for the winner would imply a swing from left to right/right to left majority. Since the Green Party was much smaller than it is today during the period investigated in Petterson-Lidbom’s paper and is now not considered
to belong to any of the established political blocks at the municipality level, this approach cannot be used. It is also rare to find pure L or R majorities close to the 50% thresholds. Municipalities close to the thresholds instead often cooperate across the traditional blocks, with the Green Party or with local parties diluting any potential pure left- or right-wing effect.

Fortunately, new techniques have developed that credibly estimate party effects. Folke (2010) presents an alternative estimation method that causally estimates the effect of an extra seat for parties on relevant outcome variables. It is an identification strategy similar to the regression discontinuity design. Folke takes advantage of the fact that seats on Swedish municipal councils are allocated by the Sainte-Lagué method and that parties can thus gain or lose seats due to small movements, not only in their own vote share but also in the distributions of other parties’ vote shares. By focusing on the minimal distance of a seat change induced by small changes in vote shares for different parties (the small changes are less than 0.25 percentage points), Folke argues that the marginal seat allocation for parties within the threshold is as good as random. The method captures the causal effect of one extra seat for a given party. But this effect is likely to be nonlinear. A marginal seat that tips the scale and gives a party membership in a ruling coalition is likely to have a different effect compared to an extra seat that does not change the ruling coalition. The identification strategy I use aims at capturing one of those nonlinearities to estimate the effect of including the Green Party in the ruling coalition, not the effect of an extra seat.

**Difference-in-differences**

I will start out by using a difference-in-differences (DiD) approach to estimate the effect of the Green Party on the number of fines.\(^\text{18}\) I use the term periods 2003-2006 and 2007-2010 as potential treatment periods. A municipality is defined as treated if it has a ruling coalition where the Green Party is included during the time of observation. The counterfactual in this case is a ruling coalition where the Green Party is not included. It is not well defined in the sense that there are many different coalitions that could be formed instead. I have, however, tried many different interactions to see whether treatment differs for different coalition formations with and without

\(^{18}\)See e.g., Blundell and MaCurdy (1999) for an introduction to DiD estimation.
the Green Party, without finding any heterogeneous effects. Therefore, I use this binary treatment.

The identifying source of variation comes from the municipalities that changed treatment status between the term periods. In addition to estimating the overall treatment effect, I will also try to see if the effect of having the Green Party in the first term period only or the second term period only (losing versus gaining treatment) is estimated to be different. The estimated equation is the following

\[ F_{it} = \nu \Gamma_{it} + T_t + M_i + X_{it} \pi + \varepsilon_{it}. \] (2.1)

The parameter of interest is \(\nu\) which measures the effect of the Green Party on the number of fines. \(F_{it}\) is the dependent variable, here normalized as the number of fines per 10,000 firms and six-month period. \(\Gamma_{it}\) is a dummy indicating whether municipality \(i\) was treated at time \(t\). \(T_t\) is a vector of time fixed effects, \(M_i\) is a vector of municipality fixed effects and \(X_{it}\) is a vector of time-varying municipality-specific covariates; see the data section for a further description, and \(\pi\) is a vector of coefficients.

For DiD to provide credible results, it must be that the treatment is as good as random conditional on covariates. As mentioned above, there is a potential problem of endogeneity due to self-selection into treatment, see e.g., Besley and Case (2000). The estimate of \(\nu\) would, for example, be biased if the inclusion of the Green party is a result of changes in electorate attitude that occur at the same time as the election and also affects the behavior of firms and/or the environmental office. To address the issue of endogeneity, I perform the IV-estimation below. But it is important to keep in mind that since the fines are based on national law, there ought not to be any changes due to changes in electorate attitudes. Further, if changes in electoral attitudes, affecting the work of the environmental offices, occurred prior to the election, we would see separate trends for the treatment and control groups. The common trend assumption is further investigated in the result section. The second important assumption for the difference-in-differences estimation, that the composition of treatment and control groups should remain unchanged before and after treatment, is self-fulfilled.

\footnote{In the text, I will write treated municipalities which can refer to both municipalities that lost/gained treatment. It should be evident from the context which type of municipalities treatment refers to.}
2.4. **THE MODEL**

**Instrumental variable approach**

The fixed effects in the DiD strategy deal with the problem of unobservable variables that correlate with the outcome and are roughly constant over time. However, there could still potentially be some variables that change over time and endogenously determine Green Party representation while correlating with fines, such as rapid changes in electoral and firm attitudes toward environmental stringency. To add some exogenous variation to the Green Party representation in ruling coalitions, I use an instrumental variable (IV) approach. Focusing on a subset of Swedish municipalities, 90 out of 290, where the election outcomes showed no clear block winner, I will use the absence of local parties as an instrument for Green Party representation in ruling coalitions. For the instrument to credibly help estimate the causal effect between the Green Party and the number of fines, the relevance and exogeneity conditions need to be fulfilled.

The relevance condition implies that the instrument should affect the probability that the Green Party is included in the ruling political majority. It is intuitive why the absence of local parties should affect this probability. If no block gained more than 50% of the seats, coalitions with parties outside the traditional blocks need to be established to form some kind of majority. A priori, there are nine different possible ruling coalitions in municipalities where the election outcome is not clear. It is basically the same set as the possible coalitions listed above excluding pure left- or right-wing rule. The possibilities are the set \{(L, GP), (L, LP), (L, GP, LP), (R, GP), (R, LP), (R, GP, LP), (L, R), (L, R, GP), (L, R, LP), (L, R, GP, LP)\}. Reducing this set by removing all alternatives including local parties, we have \{(L, GP), (R, GP), (L, R), (L, R, GP)\} i.e., it removes six out of the ten a priori possible combinations to form a ruling coalition and also increases the share of alternatives where the Green Party is included. Maybe more importantly, the absence of a local party means that coalitions involving the Green Party are the only possible ruling coalitions with the exception of coalitions across block borders.

So does the presence of a local party affect the probability of the Green Party being a member of the ruling coalition? Descriptive statistics support

\[^{20}\text{Which of these possibilities that are practically feasible depends of course on the specific election outcome in the municipality. Also on a few occasions, L or R formed a political minority to rule a municipality.}\]
this story. Table 2.3 shows the shares of ruling majorities including the Green Party in the municipalities that have/have no local party representation. The share of municipalities where the Green Party is included in the ruling coalition is much larger when there are no local parties as compared to the case where there is an additional possible coalition partner in the form of a local party.

Table 2.3: Shares of ruling majorities including GP

<table>
<thead>
<tr>
<th></th>
<th>No GP in majority</th>
<th>GP in majority</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 LP seats</td>
<td>0.36</td>
<td>0.64</td>
</tr>
<tr>
<td>LP seats &gt; 0</td>
<td>0.63</td>
<td>0.37</td>
</tr>
</tbody>
</table>

The exogeneity condition is not straightforward to validate. Here I will provide some theoretical and empirical arguments for why local party representation is as good as randomly distributed over municipalities. The only type of municipalities where local parties are underrepresented are the very largest cities in Sweden. Therefore, I omit the large city groups as defined by the Swedish Association of Local Authorities and Regions (see the appendix) from the analysis.

Local parties earned seats in roughly half (143 out of 290) of Sweden’s municipality councils in the last election. Many of these parties are named after the municipality in which they are active, such as Mariefredpartiet, Strängnäspartiet, Folkviljan i Vänersborg or they have completely generic names such as Kommunens Bästa (For the welfare of the municipality) or Rättvis Demokrati (Fair Democracy). They usually have a very specific agenda and are willing to cooperate with either block to push their issues at heart. For example, Drevvikenpartiet in Huddinge wants to form their own municipality, Mariefredspartiet is willing to form a coalition with either side to strengthen the local democracy and Bjärepartiet in Bästad wants to work across party lines to develop the local tourism industry.

This is just a small sample of a very large variety of issues local parties deal with. What I want to stress with these examples is that the issues do not seem to be tied to certain types of municipalities and that the local parties more often than not are willing to cooperate with either block to put their issues forward. Moreover, if local party representation is as good as randomly distributed, there should be no significant differences between observable variables in municipalities that have and do not have a local
2.4. THE MODEL

party representation. Table 2.4 shows descriptive statistics and a t-test on the equality of means on municipality-specific variables.

Table 2.4: Observable characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>LP seats = 0</th>
<th>LP seats &gt; 0</th>
<th>Difference</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP in ruling coalition</td>
<td>0.64</td>
<td>0.37</td>
<td>0.27</td>
<td>0.067</td>
</tr>
<tr>
<td>Population</td>
<td>22,605</td>
<td>23,680</td>
<td>1,075</td>
<td>0.67</td>
</tr>
<tr>
<td>Firms</td>
<td>2,448</td>
<td>2,406</td>
<td>42</td>
<td>0.84</td>
</tr>
<tr>
<td>Average age</td>
<td>41.4</td>
<td>42.4</td>
<td>1</td>
<td>0.01</td>
</tr>
<tr>
<td>Municipality employed %</td>
<td>9.83</td>
<td>9.80</td>
<td>0.03</td>
<td>0.87</td>
</tr>
<tr>
<td>Only elementary school %</td>
<td>12.02</td>
<td>12.25</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td>Postgraduates %</td>
<td>0.24</td>
<td>0.25</td>
<td>0.01</td>
<td>0.77</td>
</tr>
<tr>
<td>Firm share %, agriculture</td>
<td>26.2</td>
<td>28.9</td>
<td>2.7</td>
<td>0.22</td>
</tr>
<tr>
<td>Firm share %, manufacturing</td>
<td>6.8</td>
<td>7.0</td>
<td>0.2</td>
<td>0.32</td>
</tr>
<tr>
<td>Firm share %, construction</td>
<td>9.1</td>
<td>8.8</td>
<td>0.3</td>
<td>0.54</td>
</tr>
<tr>
<td>Firm share %, retail</td>
<td>13.2</td>
<td>13.0</td>
<td>0.2</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Environmental interest ratings, figure 2.1

<table>
<thead>
<tr>
<th>Interest Level</th>
<th>Not interested</th>
<th>Not very interested</th>
<th>Pretty interested</th>
<th>Very interested</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>2.00</td>
<td>23.40</td>
<td>50.00</td>
<td>20.40</td>
</tr>
<tr>
<td>%</td>
<td>3.70</td>
<td>23.00</td>
<td>52.70</td>
<td>16.20</td>
</tr>
<tr>
<td>Difference</td>
<td>1.70</td>
<td>1.40</td>
<td>2.70</td>
<td>4.20</td>
</tr>
<tr>
<td>P-value</td>
<td>0.42</td>
<td>0.92</td>
<td>0.64</td>
<td>0.34</td>
</tr>
</tbody>
</table>

*Mean values of observable characteristics in municipalities without and with local party representation in column two and three, respectively. P-values from a t-test on the equality of means in both groups are displayed in column 5.

The number of firms and population size are two variables that are very likely to be strong determinants of the number of fines in a municipality. It is encouraging to see that the difference between the mean of these variables across municipalities with and without local party representation is negligible. Except for the Green Party indicator, only one out of the ten variables turns out to differ in the two groups at conventional significance levels. The industrial structure in a municipality is likely to be an important determinant of the number of fines. They also turn out to be similar across the two groups.

Table 2.4 shows that the observable characteristics do not differ significantly between the two groups. This finding does not reject my claim that local parties are as good as randomly distributed. What cannot be shown but has to be assumed is that municipalities with and without local party representation do not differ in any significant way in terms of unobservable characteristics that also correlate with the number of fines and change over time. One such variable is environmental consciousness. A potential bias is due to the fact that the electorate has different opinions about the environ-
ment in municipalities with and without local parties. On the election day, a survey (Holmberg et al., 2006) is always made at a large random sample of Swedish polling stations. In 2006 the survey, among other things, had a focus on environmental issues. One of the questions was the following. *How interested are you in general in environmental issues?* The respondent had four different answers to choose from ranging from *not interested* (1) to *very interested* (4). Figure 2.1 shows the distribution of answers in municipalities with and without local parties.

![Figure 2.1: Interest in environmental issues](image)

The distributions are similar in both types of municipalities. Somewhat fewer are very interested in municipalities with local parties, but on the other hand, there are more that are quite interested. A t-test on shares of the different answers shows no significant differences. I also make the assumption that firm behavior does not change directly when there is a change in majority. This is motivated by the types of fines that are usually issued. In interviews with environmental inspectors, it is often stressed that many fines are the results of misunderstandings or ignorance of the law and not calculated malice (SOU 2004:37). In general, environmental inspectors consider that firms have the intention to do the right thing. But, once again, even if this assumption does not hold, it would dilute the Green Party effect rather than enhance it. For the above specified subset, I add the following first stage to equation 2.1

\[
\Gamma_{it} = \alpha LP_{it} + T_t + M_i + X_{it} \gamma + \epsilon_{it} \tag{2.2}
\]

The dummy variable \(LP_{it}\) indicates whether municipality \(i\) at time \(t\) had local party representation on its council. In the result section, I compare the
2.5 RESULTS

OLS result from equation 2.1 with the IV estimates obtained when introducing the first stage, adding covariates cumulatively to see if the estimate changes in any significant way. A well-defined instrument should not produce results that vary across specifications in any substantial way.

2.5 Results

Figure 2.2 shows the number of fines per six months and 10,000 firms comparing different ruling coalition formations with and without the Green Party. The numbers are admittedly small, but it is important to normalize fines by municipality size. Only a very small share of the total number of firms is inspected. For example, the average number of inspections in the municipalities that report these in their annual reviews is 143 (see the result section). In 2002, Sweden had around 5,500 firms in the A and B class. About 3,700 of these were inspected and a total of 135 fines were issued to this category (SEPA 2003 p.3). Normalizing by the total number of firms is thus somewhat blunt but the results do not change qualitatively when normalizing by other measures such as population or removing all firms with 0 employees.

Figure 2.2: Fines per coalition type

The numbers in figure 2.2 indicate that municipalities where the Green Party is included in the ruling coalition on average issue more fines as compared to the same coalition without the Green Party. In relative terms, the differences seem large. The differences in the number of fines between left-, right- and left + right coalitions are smaller than the differences between
The political economy of environmental regulatory compliance

the coalitions with and without the Green Party. There is no immediate reason why the number of fines should differ between left and right coalitions. The similarity between the coalitions without the Green Party is rather comforting as it looks like the Green Party is driving the differences.

Results difference-in-differences

![Figure 2.3: Average fines per 10,000 firms](image1)

![Figure 2.4: Average fines per 10,000 firms](image2)

The common trend assumption is still to be examined. Figures 2.3 and 2.4 give a visual validation of this assumption and also a preview of the main result. The figures show the trends in fines per 10,000 firms for four different municipality groups. In figure 2.3, the trend for municipalities where the Green Party was not included in the ruling coalition in the first term but was so in the second term (GPS) is shown. It is compared to the control group which consists of all municipalities where the Green Party was not included in the ruling coalition in either term (GPN). Hence, they have a similar political setting in the first term. This is also the case for figure 2.4. Here, I use all municipalities where the Green Party was included in both terms (GPA) as a control group for the municipalities where the Green
Party only was included in the first term (GPF). The control groups were assigned so that each treatment group had the same setting in the first term.

It is not obvious how one should define the exact time of treatment. New routines might take some time to be set. The data on fines is ordered in six-month blocks, January-June and July-December. I define treatment to occur on January 1st 2007, the first time period after the election. Judging from figures 2.3 and 2.4, it is not obvious that a potential treatment effect has occurred in the first post treatment period.

In the first term, where the two groups have a similar political setting with respect to the Green Party, the trends of both the treated and the control groups are similar. In figure 2.3, it seems like the inclusion of the Green Party in the ruling coalition has a positive effect on the level of fines after the election. Apart from the shift in levels, the trends in the two groups are still similar. For the municipalities where the Green Party is excluded from the coalition in the second term, it is hard to see a similar effect. The control group issues more fines on average in the first periods after the election compared to the municipalities where the Green Party has been excluded. However, this effect seems to disappear towards the end of the term period.

Judging from figures 2.3 and 2.4, the parallel trends assumption seems to be fulfilled for the treated and non-treated groups. Also the levels are similar prior to treatment. This is potentially important since large differences in levels could possibly generate different results contingent on the dependent variable specification. For all municipality groups, there is also a large upwards shift in level in 2009. This is most probably due to the fact that the enforcement of the animal welfare law was centralized at that point in time which freed up resources for the environmental office. I will remove the observations from 2009 in one specification as a robustness check.

The covariates were presented in section 2.3. In addition to the observable characteristics from table 2.4, I also control for a set of political variables. The variables are voter turnout and a dummy indicating whether the coalition is left- or right-wing based. All equations were estimated with municipality and time fixed effects. I include both Newey-West standard errors (Newey and West, 1987) for panel data and clustered standard errors at the municipality level (Bertrand et al., 2004) as they are both meant to address the correlation of standard errors within a municipality. There
are significant changes in precision when clustering. One observation is one municipality during one six-month period. All estimations were performed using Stata 12.

Table 2.5: DiD estimation

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>All</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>GPA</td>
<td>2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newey West standard errors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treat</td>
<td>1.450***</td>
<td>1.364**</td>
<td>1.344**</td>
<td>1.539***</td>
</tr>
<tr>
<td></td>
<td>0.419</td>
<td>0.612</td>
<td>0.615</td>
<td>0.584</td>
</tr>
<tr>
<td>Clustered standard errors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treat</td>
<td>1.450**</td>
<td>1.364*</td>
<td>1.344*</td>
<td>1.539**</td>
</tr>
<tr>
<td></td>
<td>0.601</td>
<td>0.799</td>
<td>0.803</td>
<td>0.745</td>
</tr>
<tr>
<td>Time F.E.</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mun F.E.</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mun Cov</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pol Cov</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ind Str</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>3526</td>
<td>3526</td>
<td>3178</td>
<td>2992</td>
</tr>
</tbody>
</table>

*Estimation of equation 2.1. Standard errors in italics. The dependent variable is the number of fines per 10,000 firms. Estimation using both Newey West (top) and clustered (bottom) standard errors. Column 3 excludes GPA municipalities, column 4 excludes observations during 2009.

The estimates are displayed in table 2.5. Overall, the results indicate that there is a positive effect of the Green Party on the number of fines in a municipality. Column 1 of table 2.5 shows the raw correlation between the number of fines and the Green Party without any fixed effects or covariates. Column 2 shows the same regression adding fixed effects and covariates. Column 3 excludes the municipalities where the Green Party was included in the ruling coalition during both terms since they do not contribute with identifying variation. Column 4 excludes the year 2009, which had a large upward shift in levels for all categories. All columns indicate that municipalities with the Green Party included in the ruling coalition issue on average about 1.4 more fines per 10,000 firms every 6 months compared to municipalities where the Green Party is absent in the ruling coalition. This is equal to about 0.15 standard deviations or one quarter of the mean. The effect of the Green Party is thus relatively large and can thus, given that
2.5. RESULTS

fines constitute a good proxy for enforcement, be inferred to have a large economic effect on the enforcement of the environmental code.

The point estimates are very stable across the different specifications. Adding fixed effects and covariates mainly seem to have an effect on precision. It is interesting to note that the removal of the observations from 2009, the year when there was a large shift in the level of fines, increases the point estimate somewhat but actually reduces the standard errors. One year evidently has quite a large impact on the precision of the estimates. Hence, it is interesting to see how the estimates vary over time. Figure 2.5 adds each six-month period post-election cumulatively.

Figure 2.5: Yearly estimated effects

The solid line shows how the point estimate evolves as time periods are added cumulatively with the dashed and dotted lines showing the 90% confidence intervals for the Newey-West and clustered standard errors, respectively. The effect is estimated to be at first increasing but then very stable over time, fluctuating around 1.4. It is also visualized how the standard errors increase in 2009 when there was a large shift in the level of fines.

The visualization of the trends in figures 2.3 and 2.4 indicated that adding the Green Party to the ruling coalition affected the level of fines but removing the Green Party did not. To study this, I split the treatment effect into two separate dummies indicating, respectively, whether the Green Party was in the ruling coalition in the first (GPF) or in the second (GPS) period. The results are displayed in table 2.6.

Column 1 shows equation 2.1 estimated using the two separate dummies confirming that it is the municipalities that gain treatment that are driving the results. Excluding the Green Party from a coalition does not seem to have a negative effect. However, clustering the standard errors makes the
Table 2.6: DiD estimation\(^a\)

<table>
<thead>
<tr>
<th>Variable</th>
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<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All GPS GPN GPF GPA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>2.315**</td>
<td>2.262**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.057</td>
<td>1.060</td>
<td></td>
</tr>
<tr>
<td>GPF</td>
<td>0.581</td>
<td>0.464</td>
<td>0.813</td>
</tr>
<tr>
<td></td>
<td>0.874</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clustered standard errors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>2.315</td>
<td>2.262</td>
<td>1.472</td>
</tr>
<tr>
<td></td>
<td>1.470</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.581</td>
<td>0.464</td>
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<td>0.921</td>
<td></td>
<td></td>
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<tr>
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<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>3526</td>
<td>2632</td>
<td>898</td>
</tr>
</tbody>
</table>

\(^a\) Estimation of equation 1 separating adding and removing treatment. The dependent variable is fines per 10,000 firms. Column 1 includes all municipalities. Columns 2 and 3 pair GPS and GPN municipalities, and GPF and GPA municipalities, respectively.

estimate marginally insignificant. There is no question, however, that what is driving the results in table 2.5 is the municipalities which are gaining treatment.

One can only speculate why there is a difference between the Green Party joining a ruling coalition and leaving it but there are several plausible reasons. Municipalities that have strong ties between local businesses and politicians might issue fewer fines, as suggested in the governmental report about environmental enforcement (Ds 2000:67). For example, if the Green Party breaks up an existing coalition, these ties might be harder to exploit.\(^{21}\) It might also be the case that it is politically difficult to motivate cut backs on environmental operations while it is more feasible to expand them. But as these mechanisms cannot be tested, I restrict myself to noting that there is a difference between the Green Party coming into the ruling coalition and leaving it.

Additional specifications were also tested where I controlled for the share

\(^{21}\) I have also estimated the effect of just a change in the ruling coalition without finding any effect.
2.5. RESULTS

of votes and mandates obtained by the Green Party and also interactions between these and the treatment variable. These turned out to be insignificant, however. The effect thus seems to come from the actual inclusion of the Green Party in the ruling coalition.

The estimates are relatively large, indicating an economically significant effect. For statistical significance, the type of standard errors matters for precision as visualized in figure 2.5. Clustering at the municipality level lowers the precision. However, the point estimates do not seem to depend on different municipality subsets or regression specifications as they remain similar across different models.

Table 2.7: Differences\(^a\)

| Year | GP 2\(^{nd}\) term | GP in no term | |Difference| |
|------|-------------------|---------------|------------------|
| 2003 | 3.67              | 3.26          | 0.41             |
| 2004 | 5.07              | 3.81          | 1.26             |
|      | 4.69              | 3.3           | 1.39             |
| 2005 | 3.62              | 3.18          | 0.45             |
|      | 3.87              | 4.48          | -0.61            |
| 2006 | 3.30              | 3.80          | -0.50            |
|      | 5.12              | 4.75          | 0.37             |

\(^a\)Difference in standardized number of fines between GPS and GPN municipalities across six-month periods.

Table 2.8: One time series\(^a\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treat</td>
<td>1.95***</td>
</tr>
<tr>
<td></td>
<td>0.48</td>
</tr>
</tbody>
</table>

\(^a\)Estimation of the time series difference (table 2.7) with Newey-West standard errors.

Obtaining the correct specification of the standard errors with only two groups is difficult. To circumvent this problem, as suggested by Donald and Lang (2007) and applied in, e.g., Petterson Lidbom and Skogman Thoursie
(2010), I also collapse the two time series in figure 2.3 into one time series. This is done by, in every time period, subtracting the number of fines for the group of municipalities where the Green Party was never in the ruling coalition from the group where the Green Party was included in the second term. This is summarized in table 2.7. The difference is regressed on a dummy variable indicating post treatment. Newey West standard errors are used to compensate for any autocorrelation and heteroskedasticity. The results in table 2.8 come out highly significant and, more importantly, very similar to the estimates in table 2.5.

Results IV

Before moving on to the estimation, I want to discuss the expected sign of any potential bias. If the inclusion of the Green Party is associated with a change in electorate and or firm attitude to environmental stringency, we would expect the estimates in table 2.5 to be biased towards zero. Instrumenting the inclusion of the Green Party would thus lead to higher point estimates. Since the effect is driven by municipalities where the Green Party is included in the second term, I use these to see how instrumenting for Green Party inclusion affects the results i.e., the estimates in table 2.9 should thus be compared to those of column 2 in table 2.6.

The estimates are much larger using the IV-approach implying that, as discussed, OLS might underestimate the Green Party effect. The point estimates of around 7 are equivalent to an increase of about 0.7 standard deviations. It should be noted, however, that a few outliers drive this relatively huge increase. Removing the top percentile based on the number of fines reduces the point estimate to around 4, a number much closer to the OLS estimates which can be seen in table 2.11 in the appendix.\(^{22}\) The standard errors have also increased drastically and the OLS estimates are well within the 95% confidence intervals for the IV-estimates. The lack of precision can be attributed to the few changes (12 municipalities) in instrument status that occurred between term periods and which are needed to identify variation due to the municipality fixed effects.

The IV estimates are imprecisely measured. However, the point val-

\(^{22}\)Removing the top percentile in table 2.5 decreases the point estimates somewhat but increases the precision for columns 1-3 and decreases the precision somewhat for the estimates of column 5.
2.5. RESULTS

Table 2.9: IV estimation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Newey-West standard errors</th>
<th>Clustered standard errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>LP</td>
<td>0.43***</td>
<td>0.43***</td>
</tr>
<tr>
<td>1st stage F</td>
<td>90.2</td>
<td>91.3</td>
</tr>
<tr>
<td>First Stage</td>
<td>Clusters standard errors</td>
<td>Second Stage</td>
</tr>
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<td>LP</td>
<td>0.43***</td>
<td>0.43***</td>
</tr>
<tr>
<td>GPS</td>
<td>7.21</td>
<td>7.26</td>
</tr>
<tr>
<td>1st stage F</td>
<td>7.09</td>
<td>7.46</td>
</tr>
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<td>Time F.E.</td>
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<td>Yes</td>
</tr>
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<td>Mun F.E.</td>
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<td>Yes</td>
</tr>
<tr>
<td>Mun Cov</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Pol Cov</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ind Str</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Observations</td>
<td>860</td>
<td>860</td>
</tr>
</tbody>
</table>

*Estimation of equation 2.1 instrumenting treatment with local parties using both Newey-West and clustered (bottom) standard errors. The dependent variable is the number of fines per 10,000 firms.

Values suggest that the OLS estimates might be biased towards zero. The F-statistics from the first-stage regression falls sharply as standard errors are clustered at the municipal level. But the most important result of table 2.9 is that given the large standard errors, the point estimates are very stable across specifications. The different point estimates are concentrated around seven and change very little when controlling for municipality, political and industrial structure covariates.

As a robustness check, I use an additional instrument to see if the estimates change. In political science, one variable that has proven to have strong predictive power for the ruling coalition in a municipality is the minimal range coalition, Bäck (2003). The minimal range coalition is defined as the coalition with the smallest ideological range out of all winning coalitions that would not have a majority without the smallest member. More specifically, all political parties are ranked on a left to right scale. Data from Riks-SOM was used for this purpose. Voters belonging to different parties ranked themselves on a left to right scale (1-5) and the average for each
party was used to place the parties along the scale.\textsuperscript{23} Local parties were put in the middle. All coalitions that were connected along this scale and also held a majority were then chosen. A subset of the coalitions that would lose the majority without its smallest member was then created. Out of this final subset, the minimal range coalition was the one with the smallest ideological range between the two outermost members. I considered membership in this coalition as random since the probability of belonging to this coalition depends on other parties’ vote share. It is not monotonically increasing in the own vote share. Membership in this coalition for the Green Party is used as an additional instrument for the inclusion of the Green Party in the ruling coalition.

The results are in table 2.12 in the appendix. Unfortunately, this instrument does not bite as well as in, Bäck (2003) which can be seen by the low F-statistics from the first stage. However, the inclusion of this additional instrument does not change the estimates in any significant way.

In all, the difference-in-differences and IV-results consistently indicate that the Green Party has a positive effect on the number of fines issued in the Swedish municipalities. The estimates are relatively large, thus implying economic significance. The precision of the estimates is sensitive to clustering but the point estimates remain positive throughout. The results are also robust to alterations of the estimation methods, both in terms of samples and regression specification.

**Potential mechanisms**

There is a number of potential mechanisms that can explain these findings. They can to some extent be evaluated using available data. Some municipalities give a detailed account of the cost of their environmental boards and the number of inspections conducted in their annual reviews. I have collected all available data from the annual reviews of Swedish municipalities for the investigated period. This means that I only have data for the subset that choose to give such a detailed account. It is, however, the only available data on covariates which can explain the increases but it comes with the caveat of the data being collected from a nonrandom subset of Swedish municipalities. About 170 of Sweden’s 290 municipalities reported

\textsuperscript{23}The parties were ranked V(1.484), S(2.141), GP(2.227), OP(2.835), C(3.581), KD(3.683), FP(3.766), M(4.186).
either or both the net cost and the number of inspections in any year during the investigated period. The unavailability of data is also the reason why the graphs show different time spans.

The trends in the graphs below belong to the municipalities where the Green Party was included in the second term period and the municipalities where the Green Party never belonged to the ruling coalition since it is in this group that the effect seems to be the strongest. Figure 2.6 shows that there was no significant change in the net cost of the environmental office before and after the election.24

Figure 2.6: Net cost of environmental office in millions

<table>
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<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
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<td>Value</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The net cost is somewhat higher in the treated municipalities. However, the trends seem to have been similar over time. The net costs do not show an abrupt change after the election which could have explained the increase in the number of fines.

Two other things that could potentially explain the increase in the number of fines in Green Party municipalities are increases in the number of inspections or a higher share of the environmental reports actually being reviewed by the municipalities. Figure 2.7 shows the average number of inspections per 1000 firms in treated and untreated municipalities. Further, firms classified as A, B or C, i.e., the more hazardous firms, can choose to submit their environmental reports via the Swedish Environmental Reporting Portal. In this database, there is information on how many of these reports that are reviewed by the environmental office in each municipality. This data is available for all municipalities. However, the database only stretches back to 2006. Figure 2.8 shows the share of reports that is reviewed in treated and untreated municipalities.

---

24 The environmental office is also responsible for health inspections and food inspections. I assume that these make up a constant share of the budget of the environmental offices.
It is seen that the number of inspections actually increased somewhat in untreated municipalities relative to treated. The difference in the share of reviewed environmental reports is constant over time in both types of municipalities. Neither of these variables seem to explain the increase in fines in treated municipalities.

One final potential explanation is that when the Green Party is in the ruling coalition, the environmental office may be able to work more independently. This cannot be evaluated by statistical methods since there is no good data but there is some anecdotal evidence that politicians try to interfere more or less directly with the inspectors’ work tasks. In a survey, published in the 2004 report to the government (DS 2000:67), 44 % of the environmental inspectors thought that political considerations impede enforcement of the environmental code. In the same report, several anecdotal examples of external pressure on the environmental office from politicians were published. For example, one local government commissioner in a municipality in northern Sweden officially apologized to a firm which received
2.6. CONCLUSIONS

... the commissioner deemed unjust. The same municipality also gave a grant to compensate a non-profit association which was also fined. Further, a senior official in south eastern Sweden stated that they sometimes fail to issue fines since the fines have an “incredibly hard impact and destroy relations between the firms and the regulator.” And in 2010, a politician on the environmental board of a suburb north of Stockholm added a special statement to the protocol in conjunction with the new guidelines for the environmental office (Protocol 2010-03-24). She wrote, among other things, that she was worried about environmental inspectors’ "overzealous inspections in order to expand their operations and secure their own jobs". She also expresses concerns that increased controls drive entrepreneurs “out of business and right into the hands of unemployment funds”. She concludes her statement by asking “[h]ow does the enforcement affect traders and businessmen.[sic] Is it possible in the long run to operate a business without suffering from the authorities’ harsh, and possibly often misdirected but devastating enforcement?"

If we assume that the Green Party weighs the tradeoff between environmental standards and business friendliness differently, these kinds of instances of undue influences should be less common in municipalities where the Green Party is represented and could be one explanation for the increase in the number of fines.

2.6 Conclusions

In this study, I have analyzed a possible implication of a local enforcement of national environmental regulation, by studying how including the Green Party in the ruling political coalition affects the number of fines issued by the environmental offices in Swedish municipalities. To overcome the problems of endogeneity, I have applied a difference-in-differences approach and also introduced some exogenous variation using instruments. The data indicates a positive effect for municipalities where the Green Party joins a ruling coalition but a zero effect when the Green Party leaves. A possible reason for this asymmetry is, e.g., that it is politically not feasible to cut back on environmental operations in a municipality while it is easier to motivate expansions. The estimates are robust to different model specifications and identification strategies but the precision depends on standard error specification.
The results show that in municipalities where the Green Party joins the ruling coalition, the number of environmental sanction charges increases on average. The findings are in line with the political economy literature on partisan politicians where parties’ and politicians’ preferences affect policy, but in this case, the policy is given but the outcome is affected through implementation. The findings can also be interpreted as signs of home bias, as suggested by Fredriksson et al. (2010) where local politicians implement locally favorable policies that may be suboptimal on a national level.

Various mechanisms behind this increase have been investigated. Although data on these factors is scarce, the number of inspections, the share of environmental reports reviewed or the net budget of the environmental office do not seem to increase in Green Party municipalities after an election. There is, however, anecdotal evidence that political pressure on environmental inspectors is sometimes exerted in municipalities to, e.g., appear more business friendly. If the Green Party is less prone to exert this undue influence, this could be a driving mechanism.

The results thus indicate that the Green Party has an effect on the application of the environmental code. But the results of this paper hinge on how good of a proxy the number of environmental fines issued in a municipality is for enforcement. Jacobsson and Källmén (2012) have studied cross section data and found that the number of fines correlates strongly and positively with other measurements such as the number of indictments and injunctions issued in a municipality. Given that the number of fines is a good proxy for enforcement, the relatively large estimates indicate that the Green Party has an economically significant effect on enforcement.

The setting with decentralized enforcement of environmental regulations is applicable also in other countries such as Germany and the U.S., and the results have implications for other areas in public policy where enforcement can be local and have externalities, such as animal welfare law, food inspections or emission control. The findings suggest that policy makers should be aware of the fact that local politicians affecting the enforcement of national legislation through possibly suboptimal actions, is not only a theoretical threat, but a real possibility.
References


2.6. CONCLUSIONS


A Appendix

Table 2.10: Municipality group definitions

<table>
<thead>
<tr>
<th>Group name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Big cities</td>
<td>Population (&gt; 200,000)</td>
</tr>
<tr>
<td>2. Suburban municipalities</td>
<td>More than 50% of the population commute to work in another municipality, most commonly to group 1.</td>
</tr>
<tr>
<td>3. Larger cities</td>
<td>(50,000 &lt; \text{population} &lt; 200,000), at least 70% living in cities.</td>
</tr>
<tr>
<td>4. Commuting municipalities</td>
<td>At least 40% of the population commute to another municipality</td>
</tr>
<tr>
<td>5. Back country municipalities</td>
<td>Population (&lt; 20,000) and (&lt; 7\ \text{people per km}^2)</td>
</tr>
<tr>
<td>6. Commodity producing municipalities</td>
<td>(&gt; 40%) of the population between 16 and 64 % employed in the commodity producing sector</td>
</tr>
<tr>
<td>7. Other municipalities, 25,000</td>
<td>Not belonging to prior groups, population (&gt; 25,000)</td>
</tr>
<tr>
<td>8. Other municipalities, 12,500, 25,000</td>
<td>Not belonging to prior groups, 12,500 &lt; population (&lt; 25,000)</td>
</tr>
<tr>
<td>9. Other municipalities, 12,500</td>
<td>Municipalities not belonging to prior groups, population (&lt; 12,500)</td>
</tr>
</tbody>
</table>
### Table 2.11: IV estimation without 100\(^{th}\) percentile

<table>
<thead>
<tr>
<th>Variable</th>
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<td></td>
</tr>
<tr>
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<td>4.35</td>
<td>5.21</td>
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<td>3.43</td>
<td>3.54</td>
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<td></td>
</tr>
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<td>5.21</td>
</tr>
<tr>
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<td>5.07</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mun Cov</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Pol Cov</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ind Str</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>860</td>
<td>860</td>
<td>860</td>
<td>860</td>
</tr>
</tbody>
</table>

*aEstimation of equation 2.1 instrumenting treatment with local parties using both Newey-West (top) and clustered (bottom) standard errors excluding the 100\(^{th}\) percentile. The dependent variable is fines per 10,000 firms.

### Table 2.12: IV estimation\(^a\)

<table>
<thead>
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<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>7.37*</td>
<td>7.35*</td>
<td>7.54*</td>
<td>7.65*</td>
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<tr>
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<td>3.89</td>
<td>3.78</td>
<td>3.93</td>
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<td>4.02</td>
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\(^a\)Estimation of equation 2.1 instrumenting treatment with minimal range coalition using both Newey West (top) and clustered (bottom) standard errors. The dependent variable is the number of fines per 10,000 firms.
Chapter 3

Pricing on the fish market - Does size matter?*

Abstract
The importance of fish size for price per kilo is studied using an inverse demand approach. Prices per kilo in different size categories of the same species differ significantly. This means that the average price for a species may change due to e.g., high-grading, growth overfishing or a changing climate which all have the potential to change the size composition of the catch. The estimates show that quantity flexibilities differ substantially across size and species while scale flexibilities in general are close to homothetic. The results imply that the effect of size on price is an important aspect to take into account when formulating regulation or policies to curb growth overfishing and high-grading.

Keywords: Fish, Inverse demand, Size, Pricing
JEL-codes: C51, Q11, Q22

*I would like to thank Frode Steen, Jonas Häckner, Jonas Vlachos and seminar participants at Stockholm University for most helpful comments and suggestions.
3.1 Introduction

Goods such as fish, meat, vegetables and fruit take time to produce. Once harvested, they are costly to store which means that they are supply constrained in the short run. For these kinds of goods, regular demand estimation, where price is a function of quantity, is inappropriate since price and not quantity is the variable that clears the market. Over the years, different inverse demand models have been suggested to estimate relationships between supply and demand of supply constrained goods. In this study, I use inverse demand models to estimate relationships between fish size and price per kilo.

The question of how changes in the catch composition affect prices is interesting for several reasons, many of which can be linked to the problem of overfishing, see e.g., Aps and Lassen (2010). First, the estimated price differences and flexibilities (inverse demand counterparts to elasticities) in this paper help explain the incentives for fishermen to engage in high-grading. High-grading is the procedure to discard less valuable fish in order to make room for more valuable fish and also to affect prices. The discarded fish usually have high mortality rates (Davis 2002). High-grading is more common for fish species where size is an important factor for price. The practice is illegal within the E.U. but monitoring is difficult for the authorities. Data on high-grading is unreliable due to the practice being illegal. Hence, few studies have been made that assess the magnitude of the problem but a few examples exist, see e.g. Kristofersson and Rickertsen (2009) who find evidence of high-grading by Icelandic fishermen and the Swedish Fishery Board (Fiskeriverket 2011) which estimates that 10 to 15% of the yearly landings of shrimp, roughly 1000-2000 tons, go to waste due to high-grading.

Second, both biologists (Almroth et al. 2012) and economists (Diekert 2012 and Quaas et al. 2010) have recently called for new regulation where age and size of fish are taken into account. Traditional fishery models based on biomass have been criticized for being overly simplistic and for failing to take into account maturity and weight structures in fish stocks (Tahvonen 2009). Recently, more realistic age-structured models have been developed, see e.g., Diekert (2012), Tahvonen (2009) or Quaas et al. (2010). Based on the findings in these papers, the authors call for regulation based on age-structured models rather than traditional biomass models. Regulation
based on age-structured models implies changed incentives for harvesting in the different size categories and a changed size composition of the stock. However, the prices in these models are fixed for each size. The results of this paper can be used to shed some light on how prices change due to changed harvesting patterns in different weight classes.

Third, growth overfishing is a serious problem for many species of fish (Diekert 2012). Growth overfishing is the practice to use gear to target fish of a more valuable size, usually larger specimen. Growth overfishing might thus disproportionally decline the share of fish of certain sizes in a stock and cause disturbances in recruitment, see e.g. Ottersen et al. (2006). Flexibilities can be used to study what happens to market prices in instances of growth overfishing. Changing market prices further change the incentives of fishermen. In general, larger fish yield higher prices on the market. Growth overfishing leads to smaller specimen on average which, in the long run, may drive fishermen to larger catches in order to keep the revenue constant.

Fourth, climate change has been linked to changes in the composition of fish stocks in the case of herring (Casini et al. 2010). As in the case of growth overfishing, flexibilities can be used to predict the effect on market prices of changes in the stock size composition due to a changing climate.

In this paper, a new Swedish data set is used to study how the size composition of the catch is related to the price of fish. Fish landed and sold in Sweden are divided according to an EU standard into different size categories (weight classes) based on the weight of the specimen caught. Fish in the different categories are then sold separately at different prices per kilo. I use the methods proposed in Brown et al. (1995) and refined in later papers such as Lee and Kennedy (2008) and perform rigorous testing in order to find the most appropriate inverse demand model to estimate quantity and scale flexibilities for the different size categories. Scale flexibilities measure the percentage change in the price of a size category in response to a proportional increase in the catch of all categories, and are the inverse demand counterparts to income elasticities. Quantity flexibilities measure the percentage change in the price of category $i$ in response to an increase in the catch of category $j$, and are analogues to price elasticities in regular demand.

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1Guttormsen et al. (2008) study optimal management of a fish stock with Darwinistic selection induced by harvesting.
Previewing the results, scale flexibilities are estimated to be close to \(-1\) for most species and size categories implying homothetic preferences. However, quantity flexibilities vary across size categories and species. The estimates have some interesting implications. For example, the increased average price in saithe over the last few years can be explained not only by falling total catch but also by a very large decrease in the catch of small saithe which is estimated to be of great importance for the prices of all size categories. Another example is incentives for high-grading. Larger plaice and common sole yield much higher prices on the market than smaller fish of the same species. An increase in the catch of large plaice is estimated to have large negative effects on the prices of smaller plaice while an increase in the catch of large common sole is estimated to have a much smaller impact on the price of smaller common sole. Hence, the incentives for high-grading are relatively larger for plaice than for common sole. Finally, new theory on fishery management using age-structured models calls for regulation based on number of fish and not biomass. This would have an impact on the size composition of the catch since the incentives to catch larger fish increase. The estimates in this paper can be used to discuss the resulting effects on prices.

The history of inverse demand estimation goes back to the early 1980s. In a seminal paper, Anderson (1980) established important theoretical properties of inverse demand models, which inspired many applied papers. The earliest empirical papers in the field of inverse demand estimation studied flexibilities between broad categories of goods. One of the most cited papers is Barten and Bettendorf’s (1989) empirical study of fish landed in Belgian ports. From a theoretical perspective, the general trend has been to move from estimating and improving upon single inverse demand models e.g., Moschini and Vissa (1992) and Holt and Goodwin (1997) to nesting existing inverse demand systems in more general models to see which one best fits the data e.g., Eales et al. (1997) and Brown et al. (1995). Besides fish, the most common markets that have been the subject of study under inverse demand are meat, fruit and vegetables.\(^2\)

Over the years, the focus on these broad markets has been replaced by a focus on more narrow markets where certain characteristics of goods

\(^2\)For fish, see e.g., Eales et al. (1997), Park et al. (2004) or Chiang et al. (2001), meat e.g., Holt (2002), fruit and vegetables e.g., Brown et al (1995) and Galdeano (2005).
3.1. INTRODUCTION

define the market. For example, using different inverse demand models, Muhammad and Hanson (2009) studied the importance of product cut and form for catfish demand in the U.S., Chiang et al. (2001) analyzed the impact of inventory on tuna prices and Galdeano (2005) studied quality effects on Spanish demand for fruit and vegetables. What these studies have in common is that they use discrete characteristics of goods to define the markets. Just as meat can be divided into e.g., poultry and beef, quality markings of fruit can divide e.g., apples into different categories.

Researchers in the field of inverse demand estimation have thus become more and more interested in the flexibilities between different characteristics of goods rather than the flexibilities between broader categories of goods. Discrete characteristics have been used to separate goods into different categories and the flexibilities among the categories have been estimated and studied. In regular demand estimation, researchers often use other structural estimation methods such as hedonic regressions to study how quality aspects affect the demand of a good and to find elasticities between different characteristics. But for supply constrained goods with discrete characteristics, inverse demand estimation is also appropriate for a simple and straightforward estimation of flexibilities.

It is worth noting that hedonic regressions have also been used for studying the fish market. Both McConnell and Strand (2000) and Carroll et al. (2001) used hedonic models to look at how quality characteristics affected the price of tuna in the Hawaiian market and the U.S. and Japanese markets, respectively. Kristofersson and Rickertsen (2004) mixed a hedonic regression approach with an inverse demand model to study, among other things, the effect of quantity changes in different size categories on the price of cod. I will compare the flexibilities estimated with my inverse demand approach in this study to the estimates in Kristofersson and Rickertsen (2004) resulting from the hedonic regression framework.³ In a broader context, this is interesting since I approach the question of the impact of the characteristics on demand from a different perspective. What further separates this study from Kristofersson and Rickertsen (2004) are the seven additional species of fish for which size flexibilities are estimated and the very different types of data sets used.

³Due to data limitations, discussed further in the paper, it is not possible to replicate Kristofersson and Rickertsen’s model with my data.
The rest of the paper is organized as follows. In section 3.2 the inverse demand models are derived. The data is presented in section 3.3. The procedure how to select the appropriate model and tests of the statistical and economic assumptions are presented and performed in section 3.4. Section 3.5 presents the results. The results are discussed in section 3.6 in relation to earlier papers, the theory of optimal management in age-structured fisheries and empirical relevance. Some final comments then conclude the paper in section 3.7.

3.2 The models

On a given market day, the supply of fish is fixed and the fishermen will sell their fish to wholesalers, restaurateurs etc. at the price that clears the market. Therefore, I assume the price to be a function of the quantity. There are many reasons for quantity being treated as an exogenous variable in fish demand estimation. Special gear is needed for different species of fish and changing gear on a fishing vessel is expensive. The fishermen do not know the price on a given market day when they catch the fish. There is also some evidence that it is difficult for fishermen to foresee the size of the catch (Asche et al. 1997, Salvanes and Steen 1994). When the fishermen have caught the fish, the quantity is fixed and storage is expensive due to the cold temperatures needed to keep the fish fresh. Therefore, the fishermen have no other incentives than to sell the catch once it is landed.

Since I assume price to be a function of the catch, inverse demand models are appropriate to estimate the exact relationship. The models are used to estimate quantity and scale effects. A quantity effect can be interpreted as a measurement of how the price of fish in size category $i$ changes for a marginal change in the quantity of fish harvested in size category $j$. The scale effect can be interpreted as how the price of fish of size $i$ is affected by a proportional increase in all other sizes caught.\footnote{For more on quantity and scale effects and their relation to their regular demand counterparts, see Park and Thurman (1999) and Houck (1965).} From the quantity and scale effects, I will calculate flexibilities (inverse demand counterpart to elasticities) to facilitate the interpretation.

Four different inverse demand models are presented below. They are based on standard microeconomic theory and differ in how the quantity
3.2. THE MODELS

and scale effects are specified. The differences are whether the effects are assumed to be constant or dependent on the shares for each size category of the total catch. It is difficult to argue on theoretical grounds which of the four models is best suited to use. Therefore, I use a synthetic model, also presented below, as an indicator to see if some of the models are rejected by the data.

There are many ways of deriving the inverted demand models; see for example Brown et al. (1995) or Barten and Bettendorf (1989). I start with a standard consumer maximization problem. A species of fish is divided into \( n \) different size categories denoted \( i = 1, 2, \ldots, n \). The consumer’s problem can be formulated in the following way:

\[
\max_{q_1, q_2, \ldots, q_n} u(q_1, q_2, \ldots, q_n) \text{ s.t. } \sum_{i=1}^{n} p_i q_i = m. \tag{3.1}
\]

Here, \( u \) is a utility function, \( q_i \) is the quantity of fish in size category \( i \), \( p_i \) is the associated price and \( m \) is the total budget. Denote \( \mu \) as the Lagrange multiplier. Then, the first-order condition for each size category \( i \) is

\[
\frac{\partial u}{\partial q_i} = \mu p_i.
\]

Summing across the first-order conditions and rewriting, inverse demand equations for each size category \( i \) expressed in relative prices, \( \pi_i = \frac{p_i}{m} \), can be derived.

\[
\pi_i = \frac{\frac{\partial u}{\partial q_i}}{\sum_j \frac{\partial u}{\partial q_j} q_j} \tag{3.2}
\]

The next step is to use the distance (also transformation) function which is dual to the expenditure function in regular demand theory, see e.g., Deaton (1979) or McLaren and Wong (2005). The distance function \( D(\hat{u}, q_1, q_2, \ldots, q_n) \equiv D(\hat{u}, q) \) tells us how a vector of quantities must be scaled to reach a given utility level \( \hat{u} \). It can be implicitly defined as

\[
u \left( \frac{1}{D(\hat{u}, q)} (q_1, q_2, \ldots, q_n) \right) = \hat{u}.
\]

The distance function is positive, continuous, linearly homogeneous, nondecreasing and concave in quantities and nonincreasing in utility. The distance function provides a convenient way of generating inverse demand systems.
since by the Shephard-Hanoch lemma, it is related to the inverse demand, expressions 3.2 (Deaton 1979):

$$\pi_i = \frac{\partial D}{\partial q_i} = \pi_i(u, q_1, q_2, ..., q_n).$$  \hfill (3.3)

To derive the models, the distance function must be defined. I start by deriving the Almost Ideal Inverse Demand system (AIIDS), analogous to the Almost Ideal Demand System (AIDS) created by Deaton and Muellbauer (1980). Let $q$ be the vector of quantities in each category. Define the distance function to be logarithmic (PIGLOG) and equal to:

$$\log D(u, q) = (1 - \hat{u}) \log a(q) + \hat{u} \log b(q)$$  \hfill (3.4)

where

$$\log a(q) = \sum_{j=1}^{n} \rho_j \log q_j + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \tilde{\eta}_{ij} \log q_i \log q_j$$

$$\log b(q) = \beta_0 \prod_{j=1}^{n} q_j^{-\beta_j} + \log a(q).$$

This specification is flexible and results in attractive testable properties in the final demand system; see Deaton and Muellbauer (1980) for its use in AIDS. Equation 3.3 can be manipulated by multiplying both sides with $\frac{q_i}{\pi_i(u,q)}$ and noting that $D(\hat{u}, q) = 1$ in optimum. By doing this and using the derivative of equation 3.4, we have that

$$\frac{\partial D(\hat{u}, q)}{\partial q_i} = \frac{\partial \log D(\hat{u}, q)}{\partial \log q_i} = w_i = \rho_i + \sum_{j=1}^{n} \eta_{ij} \log q_j - \beta_i \hat{u} \beta_0 \prod_{j=1}^{n} q_j^{-\beta_j}. \hfill (3.5)$$

$w_i = \frac{\rho_i q_i}{m}$ is category $i$’s share of the total budget and $\eta_{ij} = \frac{\hat{\eta}_{ij} + \hat{\eta}_{ji}}{2}$. Finally, inversion of 3.4 at the optimum and substituting for $\hat{u}$ in 3.5 gives the AIIDS.

$$w_i = \rho_i + \sum_{j=1}^{n} \eta_{ij} \log q_j - \beta_i \log Q \hfill (3.6)$$

---

5See, for example, Eales and Unnevehr (1994) for further details.

6$\eta_{ij} = \frac{\hat{\eta}_{ij} + \hat{\eta}_{ji}}{2}$ will later mean that I have to assume symmetry of quantity effects in the models. This assumption can (and will) be tested.
where \( \log Q = \sum_{j=1}^{n} \alpha_j \log q_j + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \eta_{ij} \log q_i + \log q_j \). I approximate \( \log Q \) with the Divisia quantity index, \( \log Q = \sum_{i=1}^{n} w_i \log q_i \), in order to simplify the estimation. This approximation has proved to work well in earlier work such as Eales and Unnevehr (1994) and Rickertsen (1998).

The restrictions on the model are adding up which implies \( \sum_i \eta_{ij} = 0 \), \( \sum_i \beta_i = 0 \), homogeneity \( \sum_j \eta_{ij} = 0 \) and symmetry \( \eta_{ij} = \eta_{ji} \). Adding up is satisfied by construction. The homogeneity restriction comes from the fact that the distance function is assumed to be homogenous of degree one, and the symmetry restriction from the definitions of \( \eta_{ij} \). Since the latter two are not satisfied by construction, they will both be tested for. Let \( d \) be the difference operator. Then, totally differentiate equation 3.6 for the differential version of AIIDS (Brown et al. 1995).

\[
d(w_i) = \sum_{j=1}^{n} \eta_{ij} d(\log q_j) + \beta_i d(\log Q) \quad (3.7)
\]

This was the derivation of the first of the four models which will be used. In this specification, the quantity and scale effects, \( \eta_{ij} \) and \( \beta_i \), are allowed to vary with the shares. In the other models, either or both are treated as independent of the shares.

It is straightforward to derive the other three models from the AIIDS, equation 3.7. Subtracting \( w_i (d(\log q_i) - d(\log Q)) \) from both sides of equation 3.7 gives the model proposed by Laitinen and Theil (1979) and which Barten and Bettendorf (1989) later denoted as the Differential Inverse Central Bureau of Statistics (DICBS). This model has its analogue in ordinary demand estimation in the CBS model introduced by Keller and van Driel (1985). The model as proposed by Barten and Bettendorf (1989) in its differential form is:

\[
w_i d \left( \log \frac{p_i}{P} \right) = \sum_{j=1}^{n} \gamma_{ij} d(\log q_j) + \beta_i d(\log Q) \quad (3.8)
\]

where \( P \) is the divisia price index analogous to the divisia quantity index above. DICBS and AIIDS share scale effects but the quantity effects differ since \( \eta_{ij} = \gamma_{ij} + \delta_{ij} w_{ij} - w_{ii} w_{ij} \), where \( \delta_{ij} = 0(1) \) if \( i \neq j \) (i.e., the Kronecker delta). The difference between AIIDS and DICBS is thus that for the DICBS, the quantity effects are treated as static but are allowed to

vary with the shares for AIIDS. The restrictions on the $\gamma'$s are analogous to the restrictions on the $\eta'$s; adding up, $\sum_i \gamma_{ij} = 0$ homogeneity, $\sum_j \gamma_{ij} = 0$, and symmetry, $\gamma_{ij} = \gamma_{ji}$.

By subtracting $w_i d(\log Q)$ from both sides of equation 3.8, the Rotterdam Inverse Demand system (RIDS) can be obtained.\(^8\)

$$w_i d(\log \pi_i) = \sum_{j=1}^{n} \gamma_{ij} d(\log q_j) + \alpha_i d(\log Q)$$

(3.9)

The RIDS share quantity effects with the DICBS but the scale effects differ. $\beta_i = \alpha_i + w_i$. The difference between RIDS and the DICBS is thus that not only the quantity but also the scale effects, are treated as static. From the definitions of the scale effects, the adding up restriction must change accordingly, i.e., $\sum_i \alpha_i = -1$.

The last model is obtained by subtracting $w_i d(\log Q)$ from the left- and right-hand side of equation 3.7. The resulting model is denoted the differential inverse NBR (DINBR) and it corresponds to the NBR model in regular demand estimation (Neves 1994). As shown in Brown et al. (1995), the DINBR can be written in its differential form as:

$$d(w_i) - w_i d(\log Q) = \sum_{j=1}^{n} \eta_{ij} d(\log q_j) + \alpha_i d(\log Q).$$

(3.10)

The DINBR model shares quantity coefficients with AIIDS and scale coefficients with RIDS. Thus, in contrast to the other models, the scale effect is treated as static while the quantity effects are allowed to vary with the shares.

To sum up, all models share right-hand side variables. The differences between the specifications are whether or not the quantity and scale effects should also depend on the share of the size categories. Table 3.1 presents the relationships between the two different quantity and scale effects.

DICBS and RIDS share quantity effects (the $\gamma'$s) which are constant while the quantity effects for AIIDS and DINBR (the $\eta'$s) are allowed to vary with the shares. Analogously, the scale effects of the RIDS and DINBR (the $\alpha'$s) are constant while the scale effects for the DICBS and AIIDS (the $\beta'$s) are allowed to vary with the shares.

Theoretically, it is difficult to argue which of the models is the most

\(^8\)See Brown et al. (1995) for a complete derivation.
3.2. THE MODELS

Table 3.1: Quantity and scale effects

<table>
<thead>
<tr>
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<th>Quantity effects</th>
<th>Scale effect</th>
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<tr>
<td>RIDS</td>
<td>$\gamma_{ij}$</td>
<td>$\alpha_i$</td>
</tr>
<tr>
<td>DICBS</td>
<td>$\gamma_{ij}$</td>
<td>$\beta_i$</td>
</tr>
<tr>
<td>AIIDS</td>
<td>$\eta_{ij}$</td>
<td>$\beta_i$</td>
</tr>
<tr>
<td>DINBR</td>
<td>$\eta_{ij}$</td>
<td>$\alpha_i$</td>
</tr>
</tbody>
</table>

$\eta_{ij} = \gamma_{ij} + \delta_{ij} w_i - w_i w_j$
$\beta_i = \alpha_i + w_i$

appropriate one for different inverse demand systems. To see if any of the models could be rejected by the data, Brown et al. (1995) showed that the four models could be nested in a synthetic demand system. Tests on the parameters of this model could then sort out some inappropriate models. This nested model shares the dependent variable with the RIDS model. Define $e_i = (1 - \theta_1) \alpha_i + \theta_1 \beta_i$ and $e_{ij} = (1 - \theta_2) \gamma_{ij} + \theta_2 \eta_{ij}$. The nested model is then written as

$$w_i d(\log \pi_i) = \sum_{j=1}^{n} [e_{ij} - \theta_2 w_i (\delta_{ij} - w_j)] d(\log q_j) + (e_i - \theta_1 w_i) d(\log Q).$$

(3.11)

Putting restrictions on the right-hand side parameters transforms the nested model into the four different inverted demand models. Table 3.2 shows the assumptions on $\theta_1$ and $\theta_2$ that transform the nested model into each of the four inverted demand models. The adding up, homogeneity and symmetry restrictions still hold, $\sum_i e_i = \theta_1 - 1$, $\sum_i e_{ij} = 0$, $\sum_j e_{ij} = 0$ and $e_{ij} = e_{ji}$.

Table 3.2: Restrictions on nested model

<table>
<thead>
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<th>$\theta_1$</th>
<th>$\theta_2$</th>
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<tr>
<td>0</td>
<td>0</td>
<td>RIDS</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>DICBS</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>AIIDS</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>DINBR</td>
</tr>
</tbody>
</table>

Estimating the nested model and then testing the restrictions in table 3.2 might reject some of the models. However, this only sorts out some models that are rejected by the data. Each model still has underlying assumptions that need to be tested for. First, the economic assumptions of homogeneity...
and symmetry are not satisfied by construction. Second, there is a range of econometric issues that need to be dealt with. It is not clear that the exogeneity of quantities is appropriate. Moreover, since this is a panel data set, there might be some problem of autocorrelation. These issues will also be tested for and potentially corrected. The methods are described in section 3.4. The model selection and estimation procedures follow Brown et al. (1995) and Lee and Kennedy (2008).

3.3 Data

The data on prices and harvest in this study is monthly data ranging from January 2003 to May 2010. Data was obtained from the website of the Swedish Fishery Board where it was also publicly available. The Swedish Fishery Board merged with other government agencies in June 2011 into the Swedish Agency for Marine and Water Management where the data is now available. The Swedish Fishery Board gathered the data from auctions, the refinement industry, wholesalers and retailers who buy the fish straight from the fishermen. All prices used in this paper have been deflated by the monthly Swedish consumer price index from Statistics Sweden. Hence, all prices in the text refer to 2003 prices.

Eight species will be the subject of this study. The reasons for these eight species to be chosen are that they are sold in size categories, the major part of the quantity traded is landed in Sweden (although this varies across species and season) and the season is long enough to provide a reasonably large number of observations. The different species are cod, common sole, haddock, hake, lemon sole, plaice, saithe and whiting. Figure 3.1 below shows the trends of harvested fish and average prices over the years 2003 - 2010.

Most species show a cyclical pattern (with the exception of whiting) in total harvest but with a large variation for a given month across years. A cyclical pattern is most apparent for hake and cod. There is a downward trend in harvested quantities for both lemon sole and cod and maybe also

---

9Due to the seasonality of fishing, the number of observations differs between the different species estimated. For some species that are harvested all year, the number of observations is close to 89 but for a few species, the number of observations is substantially smaller. For all species, data is missing in October and November of 2009.

10It is also available from the author upon request.
Figure 3.1: Trends in price and total harvest
for haddock and plaice. For all species, prices are negatively correlated with quantity. For most species, average prices do not seem to have changed to any considerable extent during the investigated period. There is a small decreasing trend in the average price for hake and plaice and what seems to be a quite substantial increase in the average price for saithe.

Fish are divided into size categories according to weight. There are three to five categories depending on the species. Each species has specific categories so a category 1 specimen of cod is not necessarily of the same size as a category 1 specimen of haddock. The different categories are presented in table 3.14 in the appendix. Table 3.3 presents average price and quantity (yearly in tons) per size category for each species.

### 3.4 Model selection

In this section, I explain how a model is selected for a given species. This is done by estimating the nested model, equation 3.11, and testing which, if any, of the models that is not rejected by the data. The underlying economic (homogeneity and symmetry) and statistical (exogeneity and autocorrelation) assumptions of the selected model are then tested. The procedure follows both Brown (1995) and Lee and Kennedy (2008).
3.4. MODEL SELECTION

I assume that all coefficients are constant over time and that there is weak separability across species. Estimating a model using all species and categories simultaneously is not feasible due to data limitations. Weak separability is a strong assumption. Asche et al. (2005) find that fish is weakly separable from meat. Some concern may be raised whether one can restrict a demand system to contain only one species of fish. This assumption is common in fish demand, see e.g., Angrist et al. (2000, whiting), Muhammad and Hanson (2009, catfish), Lee and Kennedy (2008, crawfish) and Chiang et al. (2001, tuna). In this study, testing for exogeneity of the quantities using instruments, see below, does not reject this assumption. However, this does not necessarily mean that there is no interaction between the different species. It can instead mean that the harvest of one species is not correlated with the harvest of others to any greater extent. Moreover, I have tried estimating models where, for example, the aggregated quantity and the average price of other whitefish was added to the whiting demand system. This did not alter the result in important ways but it is not clear how other species should be aggregated and added given the restrictions of my data. Hence, I estimate single species systems.

The selected model will produce quantity and scale effects which can be used to derive the uncompensated quantity and scale flexibilities. I outline the selection procedure below and motivate each test using whiting as the leading example, but I will also present and discuss the results of the other species.

Whiting is a popular food fish that is mostly caught and landed off the western coast of Sweden. It is divided into four different size categories, see table 3.3. Although it is possible to estimate the equation for each size category separately, it is likely that the error terms are correlated across equations at a given point in time. A random shock in demand at time $t$ is likely to affect all size categories. Therefore, to increase the efficiency, an iterative seemingly unrelated regression (SUR) procedure was used in Stata 11.

For all models, one observation in category $i$ at time $t$ is indexed by $i_t$. The inverse demand models are written in differential form and need to be transformed into discrete time. Hence, all differential variables are transformed into discrete form s.t. $d(\log x_{it}) = \log x_{it} - \log x_{it-1} \equiv \log \tilde{x}_{it}$. The shares are also approximated by the moving average of the last two
consecutive months, \( w_{it} = \frac{w_{it} - w_{it-1}}{2} \). Finally, an error term, \( \epsilon_{it} \), is added to each equation 3.8-3.10 and 3.11.

The error terms are subject to adding up. This makes the residual covariance matrix singular which makes it impossible to estimate the equations for all categories simultaneously. Hence, in order to estimate the models using SUR, one of the equations must be deleted during the estimation, but the results are invariant to which equation (Barten 1969). The parameters for the missing equation can then be obtained from the restrictions of the model. Then, another equation can be deleted in order to obtain standard errors for the parameters of the deleted equation.

**Nested model**

The models from section 3.2 are related and based on the same microeconomic theory but differ in the specification of quantity and scale effects. To select the most appropriate model, I start by estimating equation 3.11 and test the restrictions from table 3.2. As discussed above, the combination of the restrictions on \( \theta_1 \) and \( \theta_2 \) gives the four inverted demand models.

Formally, to test the restrictions, I first estimate the unrestricted version of 3.11 with homogeneity and symmetry imposed. Then, I estimate the four restricted versions of 3.11, corresponding to RIDS, DICBS, AIIDS and DINBR, and use a log likelihood ratio test to see which models are rejected to be nested in the unrestricted model. Table 3.4 gives the parameter values of \( \theta_1 \) and \( \theta_2 \) in the unrestricted model as well as the log likelihood values for each model. The test statistic is \( \xi = -2(L_{UR} - L_R) \). \( \xi \) has asymptotically a \( \chi^2 \) distribution, and \( L_{UR} \) and \( L_R \) are the log likelihood values from the unrestricted and restricted model, respectively. This is to be compared with the 5% critical value of 5.99. A star indicates significance and means that the model is rejected by the data. Table 3.4 presents the results of this test for whiting and all other species.
### Table 3.4: Model specification

<table>
<thead>
<tr>
<th>Fish Type</th>
<th>Unrestricted</th>
<th>$\theta_1$</th>
<th>$\theta_2$</th>
<th>$L_b$</th>
<th>$\xi^c$</th>
<th>Cod</th>
<th>$\theta_1$</th>
<th>$\theta_2$</th>
<th>$L_b$</th>
<th>$\xi^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Sole Cod</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>0.94</td>
<td>-0.02</td>
<td>498.2</td>
<td>1.03</td>
<td>0.01</td>
<td>1289.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIDS</td>
<td>0</td>
<td>0</td>
<td>317.9</td>
<td>360*</td>
<td>0</td>
<td>0</td>
<td>1028.4</td>
<td>522*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DICBS</td>
<td>1</td>
<td>0</td>
<td>496.5</td>
<td>3.55</td>
<td>1</td>
<td>0</td>
<td>1288.3</td>
<td>2.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIIDS</td>
<td>1</td>
<td>1</td>
<td>415.2</td>
<td>166*</td>
<td>1</td>
<td>1</td>
<td>940.0</td>
<td>699*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DINBR</td>
<td>0</td>
<td>1</td>
<td>298.6</td>
<td>399*</td>
<td>0</td>
<td>1</td>
<td>824.8</td>
<td>929*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Haddock Hake</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Unrestricted</td>
<td>0.97</td>
<td>-0.02</td>
<td>544.3</td>
<td>0.94</td>
<td>-0.08</td>
<td>712.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIDS</td>
<td>0</td>
<td>0</td>
<td>331.9</td>
<td>424*</td>
<td>0</td>
<td>0</td>
<td>404.6</td>
<td>615*</td>
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<td></td>
</tr>
<tr>
<td>DICBS</td>
<td>1</td>
<td>0</td>
<td>544.1</td>
<td>0.39</td>
<td>1</td>
<td>0</td>
<td>709.7</td>
<td>5.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIIDS</td>
<td>1</td>
<td>1</td>
<td>316.4</td>
<td>455*</td>
<td>1</td>
<td>1</td>
<td>360.1</td>
<td>704*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DINBR</td>
<td>0</td>
<td>1</td>
<td>209.3</td>
<td>688*</td>
<td>0</td>
<td>1</td>
<td>203.7</td>
<td>1017*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lemon Sole Plaice</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>0.97</td>
<td>-0.07</td>
<td>206.7</td>
<td>1.02</td>
<td>-0.01</td>
<td>639.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIDS</td>
<td>0</td>
<td>0</td>
<td>115.5</td>
<td>182*</td>
<td>0</td>
<td>0</td>
<td>534.3</td>
<td>210*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DICBS</td>
<td>1</td>
<td>0</td>
<td>205.4</td>
<td>2.53</td>
<td>1</td>
<td>0</td>
<td>639.2</td>
<td>0.52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIIDS</td>
<td>1</td>
<td>1</td>
<td>132.2</td>
<td>149*</td>
<td>1</td>
<td>1</td>
<td>487.8</td>
<td>303*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DINBR</td>
<td>0</td>
<td>1</td>
<td>87.5</td>
<td>238*</td>
<td>0</td>
<td>1</td>
<td>407.2</td>
<td>464*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Whiting Saithe</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unrestricted</td>
<td>0.94</td>
<td>-0.02</td>
<td>453.4</td>
<td>0.95</td>
<td>-0.01</td>
<td>543.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RIDS</td>
<td>0</td>
<td>0</td>
<td>222.7</td>
<td>461*</td>
<td>0</td>
<td>0</td>
<td>373.4</td>
<td>340*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DICBS</td>
<td>1</td>
<td>0</td>
<td>456.5</td>
<td>5.77</td>
<td>1</td>
<td>0</td>
<td>541.0</td>
<td>4.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIIDS</td>
<td>1</td>
<td>1</td>
<td>224.4</td>
<td>458*</td>
<td>1</td>
<td>1</td>
<td>396.2</td>
<td>474*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DINBR</td>
<td>0</td>
<td>1</td>
<td>103.7</td>
<td>699*</td>
<td>0</td>
<td>0</td>
<td>265.5</td>
<td>555*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


1. Log likelihood values.
2. Log likelihood ratio test of the restrictions on $\theta_1$ and $\theta_2$, $t = -2(L_{UR} - L^R) \sim \chi^2_2$. 5% cutoff value is 5.99.
For whiting, RIDS, AIIDS and DINBR are all rejected. DICBS is, however, a much more relevant candidate. Thus, for whiting, DICBS will be used for estimation. This is actually the case for all species as can be seen in table 3.4. That DICBS is the inverse model that best fits the data is not uncommon in this kind of studies, see e.g., Fousekis and Karagiannis (2001) or Brown et al. (1995).

As described in section 3.2, DICBS relies on economic and statistical assumptions which may not be appropriate. Before moving on to estimating the quantity and scale flexibilities, these assumptions will now be tested.

**Exogeneity of quantity**

I have argued intuitively for why quantity is and should be treated as an exogenous variable. I tested this assumption formally by performing a Hausman test. The estimates from the SUR estimation were compared to an alternative estimator that is assumed to be consistent notwithstanding if the hypothesis of exogenous quantities is true. For a comparison of estimates, the three-stage least square (3SLS) estimator was used. The 3SLS estimator is a combination of a two-stage least square (2SLS) estimator and the SUR estimator.

The quality of this test depends on how good the instruments are. One instrument that has been used historically is weather conditions, see e.g. Angrist et al. (2000). However, matching historical weather data from weather stations to certain fish stocks at a given point in time proved to be infeasible. I used other standard variables in the literature as instruments, namely diesel prices, twelve-month lagged variables and monthly dummies, see e.g., Eales and Unnevehr (1993), Eales et al. (1997), Matsuda (2005) or Park et al. (2004). The coefficient estimates from the 3SLS estimator were then compared with the estimates from the SUR estimator and systematic differences were tested for. If systematic differences were to be found, exogeneity of quantity would be rejected and the 3SLS estimates would be used for those species.

Thus, equation 3.8 was estimated for each category using 3SLS. The procedure was then repeated but using SUR. The coefficients from both estimation methods were then compared in a Hausman test. The resulting p-value from the Hausman test (where $H_0$ was no systematic differences in coefficients) were 0.186. Hence, exogeneity was not rejected for DICBS at
conventional significance levels. Since no systematic differences were found, the SUR estimates were used for whiting. Repeating the same procedure for all other species showed that exogeneity of quantities was not rejected in any instance.

**Autocorrelation**

To address autocorrelation, I use the procedure suggested in Park et al. (2004). Equation 3.8 is estimated for all size categories in an unrestricted system using SUR. The residuals $\epsilon_{it}$ are then stored for each category $i$. The correlation coefficient $\rho$ between the residuals was then estimated using the following equation:

$$
\epsilon_{it} = \rho \epsilon_{it-1} + v_{it}
$$

(3.12)

Note that $\rho$ is independent of size category. This is necessary to preserve the adding up feature of the data. Hence, $\rho$ is imposed to be the same when estimating equation 3.12 for each category 1-4. Finally, $\rho$ is used to transform all variables according to $\tilde{x}_{it} = x_{it} - \rho x_{it-1}$. Once this is done, the original strategy to apply SUR on the autocorrelation corrected data is restored. A Breusch-Godfrey test for each size category does not reject the null hypothesis of no autocorrelation in the transformed model.

**Homogeneity and symmetry**

As shown in section 3.2, the homogeneity and symmetry restrictions stem from the economic assumptions underlying the model. Both restrictions will be imposed during estimation. However, since they are assumptions, they can also be inappropriate. Therefore, the variables corrected for autocorrelation are used to estimate both an unrestricted DICBS and a restricted DICBS model where homogeneity and symmetry are both imposed.

The same log likelihood ratio test as for the model selection was performed to test if the restricted model is rejected to be nested in the unrestricted model. Equation 3.8 is thus estimated for each size category using SUR with and without the restrictions of homogeneity and symmetry. The test statistic is $\xi = -2(L^{UR} - L^R)$, where $L^{UR}$ and $L^R$ are the log likelihood values from the unrestricted and restricted model, respectively. $\xi$ follows asymptotically a $\chi^2_n$ distribution where $n$ is the number of restric-
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Table 3.5 reports the log likelihood values from the unrestricted and restricted models $L_{UR}$ and $L_R$, respectively. A * on the test statistic indicates that it is above the 5 % cut off level.

Table 3.5: Homogeneity and symmetry

<table>
<thead>
<tr>
<th>Species</th>
<th>$L_{UR}$</th>
<th>$L_R$</th>
<th>$\xi$</th>
<th>Cod</th>
<th>$L_{UR}$</th>
<th>$L_R$</th>
<th>$\xi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common sole</td>
<td>497.10</td>
<td>488.11</td>
<td>17.97</td>
<td>Cod</td>
<td>1303.50</td>
<td>1286.42</td>
<td>34.16*</td>
</tr>
<tr>
<td>Haddock</td>
<td>555.97</td>
<td>549.81</td>
<td>12.33</td>
<td>Hake</td>
<td>738.8</td>
<td>729.43</td>
<td>18.74*</td>
</tr>
<tr>
<td>Lemon sole</td>
<td>206.18</td>
<td>204.95</td>
<td>2.46</td>
<td>Plaice</td>
<td>656.6</td>
<td>649.62</td>
<td>13.96*</td>
</tr>
<tr>
<td>Whiting</td>
<td>456.21</td>
<td>452.10</td>
<td>8.22</td>
<td>Saithe</td>
<td>581.22</td>
<td>578.23</td>
<td>5.97</td>
</tr>
</tbody>
</table>

95 % cutoff value is $^{a}\chi^2_3$: 7.81, $^{b}\chi^2_6$: 12.59, $^{c}\chi^2_{10}$: 18.31.

Table 3.5: Homogeneity and symmetry

Neither symmetry nor homogeneity is systematically rejected for whit- ing. For hake and plaice, the test statistic is just above the 95 % cut off value. For cod, homogeneity and symmetry is strongly rejected when im- posed jointly. Testing the restrictions of homogeneity and symmetry sepa- rately, only symmetry is rejected for cod and plaice, and neither is rejected for hake. For all other species, imposing homogeneity and symmetry is not rejected by the log likelihood ratio test. Both symmetry and exogeneity will be imposted during the estimation with the saving clause that symmetry might not be an appropriate assumption for cod and plaice.

Statistical tests

Some statistical tests were also performed to test the appropriateness of DICBS. The tests are summarized in table 3.6. A Shapiro-Wilks test showed that normal distribution of the residuals could not be rejected at any con- ventional significance levels for any size category. The residuals also summed to zero at each time $t$. A RESET test for misspecification was performed by including second and third power of the explanatory variables. The F- statistics did not reject any omitted variables for any category. The p-values from the Shapiro-Wilks and RESET test are presented in table 3.6.

The results of these tests for all other species were similar. With this final statistical test, it is now time to estimate the full DICBS model with homogeneity and symmetry imposed, the result of which is presented in the next section.
### 3.5 Results

The final goal is to estimate quantity and scale flexibilities. Whiting can still serve as an example of how these are obtained. Equation 3.8 is estimated for each size category of whiting using SUR with both homogeneity and symmetry imposed. This gives the quantity and scale effects which are presented in table 3.7.

#### Table 3.7: Quantity and Scale Effects, Whiting

<table>
<thead>
<tr>
<th></th>
<th>( \bar{w}_1 \log \tilde{q}_1 )</th>
<th>( \bar{w}_2 \log \tilde{q}_2 )</th>
<th>( \bar{w}_3 \log \tilde{q}_3 )</th>
<th>( \bar{w}_4 \log \tilde{q}_4 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log \tilde{Q} )</td>
<td>0.00349</td>
<td>0.0133</td>
<td>-0.00461</td>
<td>-0.0118</td>
</tr>
<tr>
<td></td>
<td>0.00357</td>
<td>0.00503</td>
<td>0.00448</td>
<td>0.00539</td>
</tr>
<tr>
<td>( \log \tilde{q}_1 )</td>
<td>-0.00801</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.00213</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \log \tilde{q}_2 )</td>
<td>0.00212</td>
<td>-0.00884</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.00231</td>
<td>0.00486</td>
<td></td>
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</tr>
<tr>
<td>( \log \tilde{q}_3 )</td>
<td>0.00004</td>
<td>0.00240</td>
<td>-0.0266</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.00230</td>
<td>0.00387</td>
<td>0.00553</td>
<td></td>
</tr>
<tr>
<td>( \log \tilde{q}_4 )</td>
<td>0.00585</td>
<td>0.00432</td>
<td>0.0242</td>
<td>-0.0341</td>
</tr>
<tr>
<td></td>
<td>0.00272</td>
<td>0.00412</td>
<td>0.00490</td>
<td>0.00634</td>
</tr>
<tr>
<td>Obs.</td>
<td>63</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.197</td>
<td>0.125</td>
<td>0.272</td>
<td>0.276</td>
</tr>
</tbody>
</table>

*Estimation of the DICBS model, equation 3.8 for all categories using SUR. Standard errors in italics, the first row is scale effects, the dependent variable for category \( i \) at the top of column \( i \).*
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and scale effects and the quantity and scale flexibilities are the following.

\[ f_{ij} = \frac{e_{ij}}{w_i} - \theta_2 (\delta_{ij} - w_j) + w_j \phi_i \]  

\[ \phi_i = \frac{e_i}{w_i} - \theta_1 \]  

(3.13)

(3.14)

Thus, for the DICBS model, the quantity and scale flexibilities are calculated as

\[ f_{ij} = \gamma_{ij} + w_j \phi_i \]

\[ \phi_i = \frac{\beta_i}{w_i} - 1. \]

The uncompensated quantity flexibility is interpreted as the percentage change in price of category \( i \) when a one percent change in the quantity of category \( j \) occurs. The scale flexibility is the percentage change in price of category \( i \) when all quantities increase proportionally by one percent. A scale flexibility for a good equal to -1 implies homothetic preferences. That is, a one percentage increase in all quantities would result in approximately a one percent decrease in the normalized price for the good. Scale flexibilities of less than -1 imply necessities and a value greater than -1 implies luxuries. Table 3.8 presents the different flexibilities for the size categories of whiting.\(^{11}\)

Table 3.8: Flexibilities, Whiting

<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity Flexibilities</th>
<th>Scale Flexibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Category 1</td>
<td>Category 2</td>
</tr>
<tr>
<td>C1</td>
<td>-0.191</td>
<td>-0.120</td>
</tr>
<tr>
<td>C2</td>
<td>-0.229</td>
<td>-0.273</td>
</tr>
<tr>
<td>C3</td>
<td>-0.238</td>
<td>-0.222</td>
</tr>
<tr>
<td>C4</td>
<td>-0.352</td>
<td>-0.367</td>
</tr>
</tbody>
</table>

95 % confidence intervals in italics.

A 1 % increase in the quantity of the own category is estimated to

\(^{11}\)Average shares are used when calculating quantity and scale flexibilities.
3.5. RESULTS

decrease the price between 0.19 and 0.5 %, depending on category. The cross-quantity effects are estimated to between 0.12 and 0.37 %. The effects are fairly precisely estimated. Some trends are worth noting.

The own quantity flexibility is estimated to be larger than any cross-quantity flexibility. That is, a percentage change in category $i$ affects the price of whiting in category $i$ more than the price in any other category $j$. Whiting in category 4 is estimated to have a larger impact on the price of larger fish than vice versa. But while the cross-quantity flexibilities differ across categories, one striking feature is the similarity of the different cross-quantity flexibilities within a category. E.g., changes in category $i$ seem to have a relatively similar effect on all categories $j \neq i$.

Regarding the scale flexibilities, larger whiting are estimated to be more of a luxury good than smaller whiting. But all estimates are close to -1, a value which is also covered by all 95 % confidence intervals except category 2. This implies close to homothetic preferences for each different category. That is, a proportional increase in all categories decreases the price with the same proportion.

For whiting, even though small specimen have a larger effect on prices than large specimen, the average price is fairly equal (table 3.3) across categories. Small fish are, however, somewhat more expensive. Hence, for whiting, high-grading would imply discarding larger fish to make room for smaller fish. The positive effect on price of discarding large fish is smaller than the negative effect on price of replacing it with smaller fish. High-grading can be curbed through regulation. This is discussed in section 3.6.

**Flexibilities of other species**

In section 3.4, I discussed how the appropriate inverted demand model was selected for each species. The models were then used to estimate quantity and scale effects which are transformed into flexibilities to facilitate the interpretation. The analogues of table 3.8 are presented in tables 3.9 - 3.13 for the other species except cod and plaice, for which symmetry was rejected. The tables for cod and plaice are found in the appendix. The results are discussed below.
<table>
<thead>
<tr>
<th>Category</th>
<th>Quantity Flexibilities</th>
<th>Scale Flexibilities</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td></td>
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<td>-0.301</td>
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<tr>
<td></td>
<td>-0.375, -0.238</td>
<td>-0.358, -0.248</td>
</tr>
<tr>
<td></td>
<td>-0.387, -0.248</td>
<td>-0.386, -0.160</td>
</tr>
<tr>
<td></td>
<td>-0.284, -0.198</td>
<td>-0.311, -0.140</td>
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<td></td>
<td>-0.142, -0.064</td>
<td>-0.288, -0.166</td>
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<td></td>
<td>-0.057, -0.005</td>
<td>-0.045, 0.019</td>
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<td>-0.375, -0.238</td>
<td>-0.358, -0.248</td>
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<td>-0.387, -0.248</td>
<td>-0.386, -0.160</td>
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<td>-0.284, -0.198</td>
<td>-0.311, -0.140</td>
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<td>-0.142, -0.064</td>
<td>-0.288, -0.166</td>
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<td>-0.057, -0.005</td>
<td>-0.045, 0.019</td>
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95% confidence intervals in italics.
### Table 3.10: Flexibilities, Haddock

<table>
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<th>Scale Flexibilities</th>
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<tbody>
<tr>
<td></td>
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<td>Category 2</td>
</tr>
<tr>
<td>C1</td>
<td>-0.196</td>
<td>-0.184</td>
</tr>
<tr>
<td></td>
<td>-0.216, -0.173</td>
<td>-0.196, -0.171</td>
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<tr>
<td>C2</td>
<td>-0.407</td>
<td>-0.449</td>
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<td></td>
<td>-0.438, -0.377</td>
<td>-0.473, -0.425</td>
</tr>
<tr>
<td>C3</td>
<td>-0.276</td>
<td>-0.282</td>
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<tr>
<td></td>
<td>-0.305, -0.247</td>
<td>-0.304, -0.260</td>
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<tr>
<td>C4</td>
<td>-0.073</td>
<td>-0.080</td>
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<tr>
<td></td>
<td>-0.088, -0.058</td>
<td>-0.091, -0.069</td>
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95% confidence intervals in italics.

### Table 3.11: Flexibilities, Hake

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<tr>
<td>C1</td>
<td>-0.211</td>
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<td>-0.255</td>
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<td>-0.230</td>
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<td></td>
<td>-0.278, -0.181</td>
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<td>C4</td>
<td>-0.166</td>
<td>-0.211</td>
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<td></td>
<td>-0.212, -0.12</td>
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<td>-0.138</td>
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</tr>
<tr>
<td></td>
<td>-0.177, -0.098</td>
<td>-0.186, -0.131</td>
</tr>
</tbody>
</table>

95% confidence intervals in italics.
Table 3.12: Flexibilities, Lemon Sole

<table>
<thead>
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<th>Scale Flexibilities</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Category 1</td>
<td>Category 2</td>
</tr>
<tr>
<td>C1</td>
<td>-0.068</td>
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<td>-0.385</td>
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<td>C2</td>
<td>-0.501</td>
<td>-0.489</td>
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</tbody>
</table>

95% confidence intervals in italics.

Table 3.13: Flexibilities, Saithe

<table>
<thead>
<tr>
<th></th>
<th>Quantity Flexibilities</th>
<th>Scale Flexibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Category 1</td>
<td>Category 2</td>
</tr>
<tr>
<td>C1</td>
<td>-0.115</td>
<td>0.010</td>
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<tr>
<td></td>
<td></td>
<td>-0.203</td>
</tr>
<tr>
<td>C2</td>
<td>0.060</td>
<td>-0.226</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.567</td>
</tr>
</tbody>
</table>

95% confidence intervals in italics.
3.5. RESULTS

For each species, there are one or two adjacent size categories that have the largest effect on the prices of the other categories. The point estimates of the largest cross-quantity flexibilities are roughly between 0.25 % and 0.6 % depending on species. It is not the case that large or small fish in general have the largest effect, this is dependent on species. For example, small saithe have a much larger effect on the price of the other categories than larger fish, but for common sole, the largest cross-quantity flexibilities belong to the larger fish in size categories 1 and 2. The cross-quantity flexibilities are also relatively stable across categories i.e., the effect of a change in category $i$ has more or less the same effect on all categories $j \neq i$.

In general, but not without exception, $f_{ii} > f_{ij} \forall i \neq j$, that is, a change in catch of category $i$ has a larger effect on the price of $i$ than any other category $j$. However, own quantity flexibilities do not necessarily have the largest effect on the price. This seems natural since different size categories are close substitutes.

For most species and categories, the scale flexibilities are relatively close to -1, implying homotheticity. For haddock, lemon sole and saithe, the high categories have larger scale flexibilities. For those species, proportional changes in landings have larger effects on the prices of small fish. It also implies that larger fish are more of a luxury good which agrees with the descriptive data (table 3.3) where it can be seen that for these species, larger fish constitute a smaller share of the catch and are also significantly more expensive per kilo. Common sole and hake have no clear pattern.

Symmetry was rejected for cod and plaice. It is interesting to note that both are species that have a very skewed distribution towards smaller weight classes (table 3.3). Furthermore, some of the results for cod, table 3.15 in the appendix, are contrary to intuition as some flexibilities are estimated to be positive. The estimated flexibilities for plaice, table 3.16 in the appendix, do not stand out relative to the other species in any particular way. However, since symmetry was rejected for both these species, the estimates should be interpreted with some care.

Even though the appropriateness of the model was doubtful for cod, I want to briefly discuss my estimates in relation to the estimates from Kristofersson and Rickertsen (2004) who studied the relationship between cod size and price using a mixed hedonic regression and inverse demand approach. Kristofersson and Rickertsen found much smaller flexibilities,
between $-0.03$ and $-0.01$, for all cross and own quantity flexibilities across all categories. They used daily auction data from Iceland, which is a much more export oriented market. Furthermore, in my study, monthly data was used while Kristofersson and Rickertsen used daily data which might help explain the discrepancies between the flexibilities since short-run variation in quantities might not have as large an impact on price due to inventory effects. But since symmetry was rejected for cod, the estimates should be taken with a grain of salt. Thus, it is not appropriate to make a direct comparison of the estimates in Kristofersson and Rickertsen (2004) and the estimates obtained in this paper for cod.

It would be an interesting future project to explicitly compare the two methods on the same data set. Due to data limitations, it is not possible to replicate their results with my data. Kristofersson and Rickertsen use a two-stage hedonic regression method where in the first stage, prices and their standard deviations of category prices are estimated for each day from every single auction that took place. Since my data is already aggregated on a monthly level, it is not possible to use this method.

Overall, the results show that size is an important quality characteristic when estimating fish demand. There are few general conclusions to be made for the different species. The relationship between size and price is highly dependent on the species of fish.

3.6 Discussion

In general, large fish are more expensive than small fish (table 3.3) for several reasons. Economies of scale is of course one reason, filleting a fish of 2 kilos takes less time than two fish of 1 kilo while the quantity of the finished product is about the same. It could also be demand driven, consumers are willing to pay for larger fish. In a meeting with Ilona Miglacs, a marine biologist at the Gothenburg Fish Auction which is the largest trading place for fish in Sweden, she stated that “larger fish means less work and a more delicious result in the kitchen”. However, that price differs so much for different size categories means that the average price for a species can vary, not only due to changes in total harvest, but also due to long- or short-term variation in the size composition of the stock, which can be induced both by endogenous and exogenous factors.
3.6. DISCUSSION

The price structure might be a sufficient incentive for high grading. But for species that are traded in small quantities, such as common sole, it is also likely that the single fishermen can make an impact on the price. For these species, the incentives for high-grading are larger when increasing the catch of more expensive fish has little effect on the prices of other fish, and the effect of the discarded fish on the prices of other fish is large. For example, larger plaice are much more expensive than small. High-grading would mean that smaller plaice are discarded to make room for larger plaice. The effects of an increase in the catch of large plaice on the price of smaller plaice are small while the effects of a decrease in the catch of small plaice on larger fish are large. Hence, engaging in high-grading by discarding small plaice to make room for larger specimen is much more profitable than the high-grading of e.g. common sole where the relationship is the opposite.

Unfortunately, there is no data on what species are subject to high grading in Sweden. One of the main motivations of high grading is to increase the value of the catch, especially for the species where size is of importance such as shrimp where around 15% of the yearly catch are estimated to be thrown back into the water (Fiskeriverket 2011). The results from this paper highlight the differences in price, and also how changes in the size composition affect the prices in different size categories and can thus be used as indicators for the species where the incentives for high-grading are high. Since fish that are thrown back into the sea have high mortality rates, high-grading does not only have an effect on the size composition of today’s harvest but also an indirect effect on that of tomorrow. The simple fact that price differs per kilo for fish of different sizes also says something about the problems growth overfishing might create. For example, if growth overfishing of large, more valuable fish eventually decreases the average size of each fish, a given biomass will yield less on the market. This may either incentivize fishermen to harvest more fish to increase their income which can have potentially harmful consequences, or if the species have a binding cap, make fishing less profitable and further diminish the ranks of fishermen in Sweden.

Since fishermen are allowed to throw some fish back into the water, for example bycatch for which the vessel does not have any quota, it is difficult to observe high-grading. High-grading has been illegal since 2010 but the authorities cannot check whether it still occurs and early estimates indicate
that it still is a problem (Fiskeriverket 2011). To combat high-grading one could change the incentives for the fishermen. Through the selection of gear and the practice of high-grading, fishermen can influence the size of the fish they catch. So how can the incentives for fishermen to engage in high-grading and growth overfishing be reduced? To discuss this, I summarize the recent literature on regulation in age-structured fishery models in the next sub section.

### Age structured fishery models

Traditional fishery biomass models, see for example Clark (1990), have been criticized for being too blunt to be used for studying optimal management, see e.g., Quaas et al. (2010) or Tahvonen (2009). Competing models that take into account the growth and aging of stocks are not new, see e.g., Beverton and Holt (1957), but have been used more sparsely than the less complex biomass models based on Schaefer (1957). Age structured models are closer to reality in that they, for example, allow prices to differ for different sizes of fish. They also allow for the use of differentiated fishing gear such as different mesh sizes which only target parts of the fish stock.

The marginalized use of age-structured models can be attributed by the increased complexity of the models. For example, in his seminal book on managing renewable resources, Clark writes that “*including age structure in the analysis introduces significant new mathematical difficulties. Indeed, the problem of the optimal harvesting of age-distributed populations remains unsolved in general*” (Clark 1990 p. 267). However, there are earlier studies that have solved age-structured models (see Getz and Haight 1989 for a summary) but these have been criticized for relying too heavily on ad hoc assumptions for tractable numerical solutions, see Quaas et al. (2010). But with better programs and computers, these complex models can be solved with less restrictions using numerical methods, see Tahvonen (2009). So what are the conclusions for optimal harvesting and regulation from these more recent theoretical models?

Tahvonen (2009) sets up an age-structured fishery model in a discrete setting to study optimal harvesting. He finds that the lessons learnt on optimal extraction from the use of biomass models do not necessarily carry
over to the age-structured model. The main differences between optimal harvesting in biomass and age-structured models, and hence also the reasons for why it is important to base regulation on age-structured models, are the following. The optimal harvest of age-structured models does not only depend on biological factors such as in the biomass model but also on fishing technology. The conditions for the existence of optimal steady states are different. Transition paths are different in that they are always monotonic for the biomass model but may be non-monotonic for age-structured models. Pulse fishing might prove to be optimal in age-structured models but never for biomass models. Hence, basing regulation on biomass models can lead to suboptimal outcomes.

Quaas et al. (2010) use a discrete age-structured fishery model to look at the optimal harvest and discuss the consequences for regulation. They suggest that optimal harvest can be implemented by setting a single total allowable catch (TAC) and then tradable harvest quotas. Harmful overfishing is divided into two categories, growth overfishing and recruitment overfishing, which means that immature fish have been over harvested. To implement optimality in this age-structured model, the quotas should be traded in numbers of fish harvested and not on biomass. Quotas based on biomass prove not to be able to solve the problem of growth and recruitment overfishing simultaneously. Alternative instruments which can also yield first-best solutions are harvesting fees for the number of fish harvested. The fees should then differ over maturity levels (weight).

The most recent development (to my knowledge) is by Diekert (2012) who sets up a continuous age-structured model to look at harvest and regulation. Diekert confirms and strengthens the conclusions of Quaas et al. (2010), namely that any regulation should be based on the number of fish caught and not biomass. However, Diekert finds that in a continuous setting, even though ITQs based on numbers are superior to other regulation methods, it does not implement the first-best solution. Thus, he argues for complementary regulation methods such as size restrictions.

As in Tahvonen (2009) and Quaas et al. (2010), the price is dependent on fish size in Diekert (2012). However, the prices are implicitly assumed to be constant for different harvest levels. The authors argue strongly and convincingly that age-structured fishery models are better alternatives than biomass models. The conclusion for regulation is that restrictions should be
based on numbers and not biomass for regulation purposes. If implemented, this would eventually change the size composition of the catch. However, in the models, there are no general equilibrium effects on price due to changed harvest patterns in different size categories. The results of my paper show clearly that the size of the catch in the different categories affects the prices which, in turn, affect optimal management and regulation. The estimates can shed some light on how size or number based regulation affect market prices.

3.7 Conclusion

In this study, I have used inverse demand models to study the relationship between size and the price of different fish species. After a selection procedure to find the most appropriate model, quantity and scale flexibilities for six species were estimated using a DICBS model. For two species, cod and plaice, the symmetry assumption of the quantity effects was rejected. Both these species have a skewed distribution towards smaller fish. This is interesting from an applied perspective as it might point to limitations of the usefulness of inverted models.

The estimates showed that size is a crucial determinant for price per kilo and also that variations of the catch in the different size categories have very different effects on the prices of other size categories. This is interesting since the stock composition and catch can change both due to exogenous and endogenous factors, such as growth overfishing, climate change and regulation. In the longer run, this of course also changes the incentives for the fishermen.

New theory in fishery management using age-structured models calls for regulation that takes maturity and size into account. This is emphasized both by biologists and economists. In a study on the aging of Atlantic cod, Almroth et al. (2012) conclude that “the results emphasize the importance of conserving old mature fish, in particular high egg-productive females, when managing fisheries.” To improve on the regulation, economists have studied age-structured models. The main lesson from these models is that quotas should be defined in numbers and not in biomass. This gives fishermen incentives to catch larger specimen of the different fish species and will, in turn, affect the size composition of the catch which has consequences
for prices. The estimates from this paper shed some light on how prices might change for different types of regulations. For example, whiting has similar prices and landings in all size categories. Changing the incentives through regulation so that larger whiting are caught is estimated to have an increasing impact on the price on average since the effect of less small fish on price is estimated to be large and the effect of more large fish is estimated to be smaller.

The exact effect of changed incentives for fishermen on fish stocks due to new regulation is difficult to foresee. However, since the relationship between size and price is estimated to be strong and also dependent on the actual weight class, I conclude that size is an important aspect of fish demand. Biological reasons and a changing climate along with growth overfishing and high grading mean that the relationship between size and price deserves attention in future research and new regulation.
References


3.7. CONCLUSION


## A Appendix

### Table 3.14: Size categories<sup>a</sup>

<table>
<thead>
<tr>
<th>Category</th>
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<th>Category 3</th>
<th>Category 4</th>
<th>Category 5</th>
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<tbody>
<tr>
<td>Cod</td>
<td>&gt;7</td>
<td>7-4</td>
<td>4-2</td>
<td>2-1</td>
<td>1-0.3</td>
</tr>
<tr>
<td>Common sole</td>
<td>&gt;0.5</td>
<td>0.5-0.33</td>
<td>0.33-0.25</td>
<td>0.25-0.17</td>
<td>0.17-0.12</td>
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<tr>
<td>Haddock</td>
<td>&gt;1</td>
<td>1-0.57</td>
<td>0.57-0.37</td>
<td>0.37-0.17</td>
<td></td>
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<tr>
<td>Hake</td>
<td>&gt;2.5</td>
<td>2.5-1.2</td>
<td>1.2-0.6</td>
<td>0.6-0.28</td>
<td>0.28-0.2</td>
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<tr>
<td>Herring</td>
<td>&gt;0.25</td>
<td>0.25-0.13</td>
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<td>0.05-0.03</td>
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<td>Lemon Sole</td>
<td>&gt;0.6</td>
<td>0.6-0.35</td>
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<td></td>
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<td>Plaice</td>
<td>&gt;0.6</td>
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<td>0.4-0.3</td>
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<tr>
<td>Saithe</td>
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<td>3-1.5</td>
<td>1.5-4.3</td>
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<td>Whiting</td>
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<sup>a</sup>Average weight per fish in each size category.
Table 3.15: Flexibilities, Cod

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<tr>
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<td>-0.320</td>
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<td>C3</td>
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<td>-0.007</td>
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<td>C4</td>
<td>0.173</td>
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<td>-1.134</td>
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<td>C5</td>
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95 % confidence intervals in italics.

Table 3.16: Flexibilities, Plaice

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<td>Category 2</td>
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<tr>
<td>C1</td>
<td>-0.011</td>
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<td></td>
<td>-0.165</td>
<td>-0.056</td>
</tr>
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<td>C2</td>
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<td>-0.005</td>
</tr>
<tr>
<td></td>
<td>-0.146</td>
<td>0.018</td>
</tr>
<tr>
<td>C3</td>
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<tr>
<td>C4</td>
<td>-0.341</td>
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95 % confidence intervals in italics.
Chapter 4

Settlement under the threat of conflict - The cost of asymmetric information*

Abstract

I study a situation where two players disagree on the division of a good. In the first of two stages, the players can divide the good peacefully between them by signing a contract. If either or both players reject the contract, they must engage in a costly contest over the good. One of the players' valuation is assumed to be private information. The feasibility of a contract that divides the good between the players prior to the contest is determined by the expected contest outcome and thus also by the distribution of the private valuation. The findings can be applied to environmental conflicts, for example to shed some light on how a valuation study of ecosystem services in Lofoten can affect the probability of opening up the area for oil and gas exploration, and also the appropriate level of compensation to negatively affected parties.

Keywords: Contest, Bargaining, Arctic, Environmental conflicts

JEL-codes: C72, C78, Q38

*Stockholm University, eric.sjoberg@ne.su.se. I thank Jonas Vlachos, Jonas Håckner, Sergei Izmalkov, Håkan Eggert and Jens Josephson for their insightful comments. This paper is written within the Arctic Futures project and I am grateful for financial support from MISTRA.
4.1 Introduction

Imagine two players trying to determine how to divide a good between them. What happens if the negotiations break down? Some issues that cannot be settled through bargaining might have to be settled in a more costly way similar to a conflict or a contest, such as court litigations or a third party decision where the third party can be lobbied. These are costly settlement procedures that could have been avoided. Hence, to better understand the mechanisms behind conflict resolutions, it is meaningful to study bargaining under the threat of a conflict.

One main driver for conflicts that has been emphasized is the “combination of private information about resolve or capability and incentives to misrepresent these” (Fearon 1995 p.409). In this paper, I aim at further exploring this mechanism and what it means for the possibility of avoiding conflicts. More specifically, I use a setting that combines bargaining and contests to study how private information affects the feasibility of a peaceful bargaining solution that would save the players from expending costly and wasteful effort in a contest.

I set up a two-stage game with two players, 1 (she) and 2 (he). Both players have an interest in acquiring a good. The good can be considered as, for example, a piece of land, a contract, or a favorable outcome in a parliamentary decision. Each player has an individual valuation of the good. Player 1’s valuation is common knowledge but only the distribution of player 2’s valuation is commonly known. The exact value, which determines player 2’s type, is private information.

In the first stage of the game, an external party presents a contract that specifies how the good is to be divided between the players. If both players accept the contract, the game ends and the good is divided accordingly. Should either or both players reject the contract, a second stage contest ensues where the players invest in costly effort in order to obtain the good. I study how asymmetric information determines whether it is possible to divide the good so that player 1 and all types of player 2 prefer to settle rather than to engage in a contest, i.e., does a division exist that guarantees a peaceful outcome? A peaceful outcome is desirable from an efficiency perspective since the resources spent on effort in a contest only contribute to rent dissipation.
4.1. INTRODUCTION

My paper primarily relates to settlement models; see Daughety and Reinganum (2008) for a survey. More specifically, my contribution to this literature is that I fully endogenize the second stage by introducing a contest that will determine the players’ decision of whether or not to settle in the first stage. This set up enables me to study how asymmetric information on valuations have an impact on the expected contest outcome and, consequently, the settlement decision. Earlier litigation models commonly make exogenous assumptions about the trial stage, for example about the probability of winning (e.g., Bebchuk 1984, Reinganum and Wilde 1986 or Wärneryd 2010), or the cost of engaging in a contest (e.g., Daughety and Reinganum 1999, Friedman and Wittman 2006, or Spier 2007). While asymmetric information is included in these models, it does not have any direct impact on the cost of not settling or winning probabilities, which are variables that clearly affect settlement decisions. By introducing a contest, I am able to endogenize these variables and explore a new mechanism through which uncertainty affects the settlement decision, namely how asymmetric information affects the consequences of not settling. This has policy implications for how new information, such as valuation studies in environmental conflicts, can affect settlement possibilities.

I also make a small contribution to the contest literature by expanding the model in Hurley and Shogren (1998, HaS henceforth) by studying the effect of asymmetric information not only on equilibrium efforts, but also on equilibrium expected profits. Studies on contests commonly focus on equilibrium efforts since these determine the rent dissipation. In my study, the decision of whether or not to settle in the first stage is determined by expected profits, which are affected by both players’ effort. Hence, I must explicitly study the effect on the expected profits.

The results from my study are the following. The feasibility of a peaceful solution depends on players’ expected contest profits. If the contest implies low rent dissipation, players are inclined to reject peaceful solutions and try to grab the whole good in the second stage. The expected contest profits depend on the mean and the variance of the players’ relative valuation. The only change that always makes a peaceful contract more feasible is a lower mean of the relative valuation, indicating that the informed player is likely to have a higher valuation, when the uninformed player believes herself to be the contest favorite. This would make the contest a worse alternative
for both players. Increased uncertainty, represented by a higher variance in the distribution of the privately informed player’s valuation, does not have any clear effect on the feasibility of a peaceful solution since it makes the uninformed player worse off in a contest and the informed player better off in a contest (more and less prone to settle in the bargaining phase, respectively).

Contests with one-sided asymmetric information are often used to study environmental conflicts, such as conflicts over land use between firms and the general public, i.e., resource extraction versus preservation (Moriath and Münster 2010, Hurley and Shogren 1997). This is motivated by the fact that the economic profitability of a resource is often well studied and publicly available while estimates of the value of the ecosystem and environmental services to the general public, such as the value of pristine nature, are unknown to firms. I will discuss the policy implications of the results in an Arctic context since land use conflicts are currently taking place in the Arctic and are also projected to become more common with increased accessibility to natural resources due to global warming (Dodds 2010).\(^1\) A special mean for mitigating conflicts that is sometimes used in the Arctic already today is side payments. I will discuss the findings of my model in terms of how information affects the feasibility of using side payments as a mechanism to divide a good in practice and avoid conflicts.

Some Arctic examples where this model can apply are the conflicts between fishermen and petroleum companies in Lofoten Norway, between home owners and mining companies in Kiruna Sweden, and between reindeer herders and the Russian oil industry on the Yamal peninsula. New valuation studies that also incorporate non-market goods, e.g., environmental services and valuations of a pristine nature, may reduce disagreements over appropriate compensation, increase the likelihood of peaceful solutions and thus reduce costly lobbying, see e.g., St. Meld (2010) or Lemker and Karlsson (2012). In these examples, firms are likely to consider themselves contest favorites due to the relatively high economic valuation of their activities.\(^2\) If non-market valuation studies provide new information that increases the

\(^{1}\)It should be clear, however, that the model is also applicable to other environmental conflicts in other regions of the world.

\(^{2}\)For example in Lofoten, the value of oil extraction is estimated to be 105 billion Norwegian kroner and the present value of the fishing industry is estimated to be 25 billion kroner (St. Meld 2010).
expected value of fishermen’s or homeowners’ valuations, this would then fulfill the conditions for when new information increases the likelihood of a peaceful solution. The policy implication is that to increase the likelihood of both sides accepting side payments in land use conflicts, compensation should not only focus on economic aspects, which often seems to be the practice (LKAB guidelines, St. Meld 2010), but also consider non-market values.

The rest of the paper is organized as follows. The model is developed and solved in section 4.2. The results are presented and discussed in section 4.3. To facilitate the interpretation of the results, I provide some specific examples in section 4.4 to show how new information can affect the feasibility of a peaceful solution. The empirical relevance of the model is discussed in section 4.5. Finally, section 4.6 wraps up the paper with some concluding comments.

4.2 The model

Players 1 and 2 (she and he), both risk neutral, desire a good. For expositional reasons, I assume the good to be divisible so that side payments between the players are made using parts of the good. Player 1 has a valuation of the good equal to $v_1$. To model private information, I define player 2’s valuation of the good to be a random variable $v$ distributed over an interval $[v, \bar{v}]$. Only player 2 knows the realization $v_2$, which also specifies his type. The distribution of $v$ is common knowledge. It has a cumulative distribution function $G(v)$ and an associated probability density function $g(v)$. It will prove to be beneficial to have a higher valuation. Therefore, I will sometimes call a player with a higher (lower) valuation a stronger (weaker) player.

The game is played over two stages. In the first stage, an external party formulates a contract that specifies a division of the good between the players. If both players sign the contract, the good is divided between them and the game ends. If either or both players reject the contract, stage two commences. In this stage, both players try to obtain the entire good in a contest through investment in costly effort that affects the winning probabilities. The resources spent on effort are a welfare loss due to the contest. Solving the conflict at an earlier stage is thus a more efficient
There are many ways of setting up a contest, see Corchón (2007) for a survey. In my paper, the contest stage is set up as the one-sided asymmetric information model by Hurley and Shogren (1998, HaS). In a contest, each player has a probability of winning determined by both the player’s own effort and the other player’s effort. To increase the own probability of winning, player 1 and 2 invest in efforts $x_1$ and $x_2$. The probability of winning and obtaining the entire good is specified by a contest success function $p(x_1, x_2(v_2))$. Consequently, the probability that player 2 obtains the entire good is $1 - p(x_1, x_2(v_2))$. It is natural to assume that $p(x_1, x_2(v_2))$ is increasing in $x_1$ and decreasing in $x_2$. Investing in effort is costly and comes at a marginal cost equal to unity.\(^3\) In order to obtain analytically tractable solutions, the contest success function is specified to be the widely used\(^4\) logit contest success function (see Tullock 1980 for origins) i.e.,

$$p(x_1, x_2(v_2)) = \frac{x_1}{x_1 + x_2(v_2)}$$

The game is solved by backward induction. Thus, I start by deriving the equilibrium outcome in the contest stage. The expected profits are needed in order to compare them to the profits the players can obtain by accepting the contract in the bargaining stage. Players 1 and 2 can thus choose either to divide the good peacefully or engage in a costly contest in order to obtain the entire good.

The Contest

Given the setup, the expected payoffs $E[\pi_i]$ for player 1 and for a given type of player 2 in the contest are the following.

$$E[\pi_1] = \int_v^6 \frac{x_1}{x_1 + x_2(v)} v_1 dG(v) - x_1$$

$$E[\pi_2|v_2] = \frac{x_2}{x_1 + x_2} v_2 - x_2$$

\(^3\)The exact specification of the cost function is not important for the main results of the model, see Allard (1988).

\(^4\)See, for example, HaS, Schoonbeek and Winkel (2006) and Slantchev (2005). HaS also discuss the generalizability of the results to other contest success functions.
4.2. THE MODEL

This is essentially the contest presented in HaS. Before presenting my own contribution to this contest model, the effect of information on equilibrium profits, I summarize the main intuition and propositions of HaS over the next few pages. The following definitions from HaS will prove to be useful.

**Definition 1.** Define the willingness to waste, \( \beta \), to be the share of her valuation that player 1 is willing to spend on effort in equilibrium i.e., \( \beta = \frac{x_1^*}{v_1} \).

**Definition 2.** Let \( \rho(v_2) = \left(\frac{v_1}{v_2}\right)^{1/2} \) define the relative resolve. Denote the expected value and variance of the relative resolve to be \( E[\rho(v)] = \mu \) and \( Var[\rho(v)] = \sigma^2 \), respectively.

The willingness to waste represents the share of her valuation that player 1 is willing to expend in order to obtain the good. The relative resolve shows the relationship between the two players’ valuations. The larger the value of the relative resolve, the stronger player 1 is relative to player 2 on average.

Using definitions 1 and 2 and assuming an interior solution, the equilibrium efforts of player 1 and all types of player 2 can be shown to be (see appendix), respectively,

\[
x_1^* = \beta v_1 \tag{4.3}
\]

\[
x_2^*(v) = v_2 \left[ \beta^{3/2} \rho(v_2) - \beta \rho^2(v_2) \right] \tag{4.4}
\]

where the equilibrium expected value of the willingness to waste expressed in terms of mean and variance of the relative resolve is

\[
\beta = \left( \frac{\mu}{1 + \mu^2 + \sigma^2} \right)^2. \tag{4.5}
\]

For the rest of this section, I assume that \( \mu > (1 - \sigma^2)^{1/2} \) i.e., the probability that player 1 is much weaker than player 2 is low. This assumption will later

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5HaS also study the effects of differences in ability to exert effort by introducing a player-specific coefficient to the efforts in the contest success function. While this could be an interesting extension, it does not affect my main results.

6As shown in HaS, given the functional form of the contest success function, the solutions to the first-order conditions of 4.1 and 4.2 are unique. Player 1 always exerts a positive effort. For all types of player 2 to exert a positive effort, the lowest valuation cannot be relatively much smaller than player 1’s valuation. The exact condition can be derived from equation 4.4.
facilitate the analysis of the effect of variance on equilibrium profits. This is also likely to be the case in the suggested empirical examples; the economic value of oil is vastly greater than the economic value of the fishery even with very low discount rates (St. Meld 2010). The following definitions from HaS will also prove to be important.

**Definition 3.** Define player 1 to be the expected favorite (underdog) if her expected probability of winning is greater (smaller) than player 2’s expected probability of winning, i.e., if $E[p(x_1, x_2(v))] > (<) \frac{1}{2}$. Define player 2 to be the true favorite (underdog) if his probability of winning is greater (smaller) than player 1’s probability of winning, i.e., if $p(x_1, x_2(v)) < (>) \frac{1}{2}$.

After simplifications, player 1 being the expected favorite is equivalent to (see the appendix)

$$\mu > [1 + \sigma^2]^{1/2}. \quad (4.6)$$

Similarly, player 2 is the true favorite if

$$\mu[2\rho(v_2) - \mu] < 1 + \sigma^2 \quad (4.7)$$

Some things are worth noting. First, player 1 can never be the expected favorite if the expectation of the relative resolve is less than 1. It is, however, possible for player 1 to be the expected underdog even if the expectation of the relative resolve is larger than 1 if the uncertainty (variance) is sufficiently large. Second, the more uncertainty in terms of variance, the higher is the likelihood that player 1 is the expected underdog. Third, player 1 being the expected favorite does not imply that player 2 is necessarily the true underdog. And finally, for a given type, player 2 is more likely to be the true favorite the more uncertainty there is in the form of variance in the relative resolve.

In order to study the effect of new information on profits, a good stepping stone is to study the effect of new information on equilibrium efforts. This is done in propositions 1 and 2 of HaS. The propositions can be proved by direct differentiation of equations 4.3 and 4.4. The proof can be divided into two parts: (i) the effect of changes in mean or variance of the relative resolve on the willingness to waste, $\beta$, and (ii) the effect of $\beta$ on equilibrium efforts. The first part will be useful later and I state it below as a lemma:
Lemma 1. An increase in the variance of the relative resolve always decreases the willingness to waste. An increase in the mean of the relative resolve increases (decreases) the willingness to waste if player 1 is the expected underdog (favorite).

Proof. This can be proven by direct differentiation\(^7\) of equation 4.5 with respect to \(\mu\) and \(\sigma^2\), and applying definition 3.

\[
\frac{\partial \beta}{\partial \sigma^2} = -\frac{2\beta^2}{\mu^2} < 0 \tag{4.8}
\]

\[
\frac{\partial \beta}{\partial \mu} = 2 \left[ 1 - \mu^2 + \sigma^2 \right] \frac{\beta^3}{\mu^2} \tag{4.9}
\]

I restate propositions 1 and 2 of HaS, where a full proof can also be found, below and give them a slightly different interpretation.

**HaS 1.** A higher variance of the relative resolve decreases player 1’s equilibrium effort. If player 2 is the true underdog (favorite), his equilibrium effort is increasing (decreasing) in the variance.

**HaS 2.** If player 1 considers herself to be an expected favorite, she lowers her equilibrium effort in response to a higher mean of the relative resolve. A player 2 who is the true favorite (underdog) in turn responds by decreasing (increasing) his optimal effort. If player 1 considers herself to be an expected underdog, she raises her equilibrium effort in response to a higher mean of the relative resolve. A player 2 who is the true favorite (underdog) in turn responds by increasing (decreasing) his optimal effort.

The intuition behind the first proposition from HaS is the following. Interpreting variance as risk, increased variance makes player 1’s effort a more risky input through decreasing her marginal utility of effort and thus also decreasing her equilibrium effort even though she is risk neutral (HaS). If the contest becomes closer due to this, i.e., player 2 is the true underdog, he responds by expending more effort. If player 2 is instead the true favorite,

---

\(^7\)Taking the derivative of an expression w.r.t. \(\mu\) or \(\sigma^2\) is done keeping the other variable constant throughout the paper.
he decreases his effort since player 1 is now a weaker opponent; player 2 can still maintain the upper hand in the contest with less effort.

The second proposition from HaS has the following intuitive interpretation (see also table 4.1). If player 1 is the expected favorite and the mean of the relative resolve increases, she will expend less effort since she thinks she will face an on average weaker opponent. If player 2 is the true favorite, he will respond by decreasing his effort since he now faces weaker competition. As a favorite, player 2 can now relax. If player 2 is instead the true underdog, the contest becomes closer and he will increase his effort in order to take his chance. If player 2 is a true favorite, he foresees this and increases his effort in order to keep his lead. If player 2 is instead a true underdog, he will respond by decreasing his effort since he now faces an even stronger opponent; he gives up.

Up to this point, the results have been a summary of HaS with some new interpretations. I will now expand their theory by also studying the effect of new information on equilibrium profits. Using the concepts of willingness to waste and relative resolve, the equilibrium profits can be rewritten in the following way

\[ E[\pi_1] = v_1 \int_{\frac{\mu_2}{\sigma^2}}^{\frac{\mu_1}{\sigma^2}} \frac{x_1^*}{x_1^* + x_2^*(v)} dG(v) - x_1^* = v_1 \beta (\mu^2 + \sigma^2) \] (4.10)

\[ E[\pi_2 | v_2] = v_2 \frac{x_2^*(v_2)}{x_1^* + x_2^*(v_2)} - x_2^*(v_2) = v_2 \left( 1 - \beta^2 \rho(v_2) \right)^2. \] (4.11)

The effect of new information on equilibrium profits is summarized in proposition 1 below.

**Proposition 1.** (i) An increase in the variance of the relative resolve always makes player 1 worse off and always makes player 2 better off, regardless of who is the expected and/or true favorite and who is the expected and/or true underdog. (ii) An increase in the mean of the relative resolve always makes player 1 better off and makes player 2 better off if player 1 is the expected favorite but worse off if player 1 is the expected underdog.
4.2. THE MODEL

Proof. (i) For player 1, direct differentiation of equation 4.10 yields

\[
\frac{\partial E[\pi_1]}{\partial \sigma^2} = v_1 \beta \frac{1 - \mu^2 - \sigma^2}{1 + \mu^2 + \sigma^2} < 0.
\]  

(4.12)

For player 2, the sign of the effect is opposite to the sign of the effect of an increased variance on the willingness to waste. To see this, note that a direct differentiation of equation 4.11 yields

\[
\frac{\partial E[\pi_2]}{\partial \sigma^2} = \frac{d\pi_2}{d\beta} \frac{d\beta}{d\sigma^2} = \left( \rho(v_2)^2 - \frac{\rho(v_2)}{\beta^{1/2}} \right) \frac{d\beta}{d\sigma^2} > 0 \text{ if } \frac{d\beta}{d\sigma^2} < 0
\]

since multiplying both sides by \( \beta \)

\[
\left( \rho(v_2)^2 \beta - \rho(v_2) \beta^{1/2} \right) \frac{d\beta}{d\sigma^2} = -\frac{x^*_2}{v_2} \frac{d\beta}{d\sigma^2} > 0 \text{ if } \frac{d\beta}{d\sigma^2} < 0.
\]

The application of lemma 1 concludes the proof of proposition 1 part (i). The proof of part (ii) is analogous. Also for the effect of an increased mean on player 2’s profit, the sole determinant of the sign is the sign of the effect of an increased mean on the willingness to waste.

A higher variance of the relative resolve always decreases the expected profit for player 1. All types of player 2 are better off with more uncertainty. An increased mean, which indicates that player 1 becomes relatively stronger, is always beneficial for player 1. If player 1 is the expected underdog, player 2 is worse off. However, if player 1 is an expected favorite, all types of player 2 are actually better off if player 1 becomes relatively stronger on average. This implies that both players’ expected profits may increase at the same time, i.e., for an increased mean of the relative resolve when player 1 is the expected favorite. The intuition is that player 1, who already is confident of winning, thinks that he faces an even weaker opponent and can relax some of his effort while still being better off in expectation. Player 2, whose type is fixed, thus faces a weaker opponent so regardless of being the true favorite or the underdog, he is also always better off.

From the proof of proposition 1 follows a convenient corollary to use when predicting the effect on player 2’s profit of any type of new information.

**Corollary 1.** For any type of player 2, the effect on the expected profit of an increased mean of the relative resolve goes in the opposite direction of
the effect on player 1’s equilibrium effort. The same holds for an increase in the variance of the relative resolve.

Proof. Follows directly from the proof of proposition 1

Corollary 1 implies that player 2 is not necessarily better or worse off just because player 1 perceives him as stronger or weaker. The effect depends on the change in player 1’s equilibrium effort and is thus solely determined by whether or not player 1 considers herself to be the expected favorite or underdog.

Table 4.1 summarizes the effect of new information on equilibrium efforts and expected profits for all combinations of expected and true favorites and underdogs.

Table 4.1: Effects of new information on efforts and profits

<table>
<thead>
<tr>
<th></th>
<th>Increased variance</th>
<th></th>
<th>Increased mean</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P1 expected favorite</td>
<td>P1 expected underdog</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2 true favorite</td>
<td>( x_1^\downarrow, x_2^\downarrow, \pi_1^\uparrow, \pi_2^\uparrow )</td>
<td>( x_1^\downarrow, x_2^\downarrow, \pi_1^\downarrow, \pi_2^\uparrow )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P2 true underdog</td>
<td>( x_1^\downarrow, x_2^\uparrow, \pi_1^\downarrow, \pi_2^\uparrow )</td>
<td>( x_1^\downarrow, x_2^\uparrow, \pi_1^\downarrow, \pi_2^\uparrow )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The relationship between efforts and expected profits varies. New information that implies a higher (lower) equilibrium effort does not necessarily imply higher (lower) profits. For example, player 1 is always better off with an increased mean. For an expected favorite, this is achieved through exerting lower effort while an expected underdog achieves it through increased effort. And player 2 is always better off with an increased variance but he can achieve this through either lower or higher effort depending on whether he is a true favorite or underdog.

Bargaining

In the first stage, the players are faced with the decision of whether or not to accept a contract, suggested by an external party, which specifies
4.2. THE MODEL

the division of the good between them without having to exert any effort.\footnote{The contract is suggested by an external party. An interesting venue for further research would be to study different bargaining protocols such as Nash bargaining or the Kalai-Smorodinsky solution, alternatively let the players themselves propose the contract. However, my focus is on studying whether there is any possible division of the good that satisfies both players using the equilibria profits from the contest as threat points.}

This decision depends on the expected profits in the contest derived in the previous section. More specifically, the contract specifies $\theta$, i.e., the share of the good received by player 2. I define a contract to be peaceful if it is accepted by all types of player 2 as well as player 1. The payoff to player 1 if both players accept the contract is then $(1 - \theta)v_1$ and similarly for player 2, his payoff in case the contract is accepted by both players is $\theta v_2$. Note that since player 2 receives the same share of the good regardless of type, this implies that player 1 cannot infer any information about the type of player 2 by observing $\theta$.

For a player to agree to a peaceful contract, a participation constraint needs to hold. If the participation constraints hold for all players, they imply that player 1 and each type of player 2 are better off by signing the contract than by rejecting the contract and thus engaging in a contest. The participation constraints for player 1 and 2, respectively, are

\[
G(\hat{v})(1 - \theta)v_1 + (1 - G(\hat{v}))\pi_1^*(v|v > \hat{v}) \geq \pi_1 \quad (4.13) \\
\theta v_2 \geq \pi_2. \quad (4.14)
\]

The left-hand sides of equations 4.13 and 4.14 are the expected payoffs for player 1 and 2 if they accept the contract. The right-hand sides are the expected payoff for each player in a contest. As long as the expected payoff in a peaceful solution is greater than or equal to the expected profit in a contest, the players will accept the suggested division of the good.

For player 1, the profit from accepting the contract depends on the share of player 2 types that accepts and rejects the contract. If, for example, all types with $v_2 > \hat{v}$ reject the contract, then player 1 faces a probability equal to $1 - G(\hat{v})$ to have to enter a contest even though she accepted the contract. However, in this contest, she learns some information, namely that $v_2 > \hat{v}$ which she may use to update her optimal strategy in the second stage. If player 1 rejects the contract herself, she loses this source of information.\footnote{This assumption can be relaxed without any important changes to the main result.}
Settlement under the threat of conflict

Naturally, also player 2 knows that a rejection of the contract reveals some information of his type which would affect his expected profit. This is taken into account by him when calculating the optimal strategies in the contest stage. In the case of a peaceful contract $\hat{v} = \bar{v} \Rightarrow G(\bar{v}) = 1$ which means that conditions 4.13 and 4.14 become symmetric. In this case, player 1 runs no risk of having to enter a contest given that she accepts the contract herself.

4.3 Results

I focus on equilibria involving pure strategies. There are two types of equilibria involving pure strategies, pooling and separating equilibria. One pooling equilibrium occurs if player 1 accepts the contract and all types of player 2 accept the contract.\footnote{Another trivial pooling equilibrium would be one where all players reject the proposed contract. However, this is clearly not a peaceful equilibrium.} Since all types of player 2 choose the same strategy, player 1 cannot use the decision by player 2 to make an inference about player 2’s type. This pooling equilibrium is equal to a peaceful contract since all players accept the contract and the contest stage never occurs.

The second type of equilibrium is a semi-separating equilibrium. In this type of equilibrium, all types of player 2 up to a type $\hat{v}$ accept the contract and all other types reject the contract. This strategy reveals some information about the type of player 2 which has consequences for the equilibrium profits in the contest stage. Since a semi-separating equilibrium leads to a contest with some probability, it is not a peaceful equilibrium but I will also comment on the conditions for the existence of this type of equilibrium.

An important determinant of any equilibrium are the beliefs player 1 is allowed to hold about player 2’s type. Player 1’s beliefs are determined by the distribution of $v$ in the first stage since it is always reached. In a peaceful equilibrium, the second stage is never reached so Bayes’ rule does not apply and player 1’s out of equilibrium beliefs must be specified. I require player 1’s out of equilibrium beliefs to be formed using passive conjectures (p.142ff Rasmussen 2001). This means that player 1 retains her prior after observing out of equilibrium actions. This limits the out of equilibrium beliefs that are specified in the Bayesian Perfect equilibrium later. Intuitively, player 1 believes that every type of player 2 has the same probability of making a
4.3. RESULTS

mistake and playing his off equilibrium strategy. In an equilibrium where the second stage is reached with positive probability, player 1’s beliefs are determined by Bayes’ rule.

I start by studying the conditions under which a pooling equilibrium exists. In a contest, the player 2 type with the highest valuation gets the highest expected profit. Therefore, to confirm that the participation constraint holds for all types of player 2, it is sufficient to check that it holds for the strongest type. Hence, if a pooling equilibrium exists, using equations 4.10 and 4.11, the explicit versions of conditions 4.13 and 4.14 are

\[(1 - \theta)v_1 \geq \pi_1^* = v_1 \beta (\mu^2 + \sigma^2) \]  \hspace{1cm} (4.15)

\[\theta v_2 \geq \pi_2^* = \bar{v}_2 \left(1 - \beta \frac{1}{2} \rho(\bar{v}_2)\right)^2. \]  \hspace{1cm} (4.16)

The left-hand sides of equations 4.15 and 4.16 are the payoffs for player 1 and 2, respectively, if they accept the contract. This gives player 1 a share of the good equal to \(1 - \theta\) and player 2 a share equal to \(\theta\). The right-hand sides of the equations are the off-equilibrium contest profits if a player were to deviate from the peaceful equilibrium and reject the contract.

If there exists at least one \(\theta\) that simultaneously makes both 4.15 and 4.16 hold, there exists a pooling equilibrium. The equations thus determine when a peaceful solution is feasible and the conditions can be summarized in a proposition.

**Proposition 2.** A peaceful contract is feasible if player 1’s and player 2’s expected profits in the contest are not too large, or more specifically; if the sum of the expected profits for player 1 and the highest type of player 2 as a share of their respective valuations does not exceed 1.

Proof. By dividing each condition in equations 4.15 and 4.16 by \(v_1\) and \(\bar{v}_2\), respectively, and then adding the left-hand and right-hand sides, the two equations together imply that a sufficient condition for a peaceful contract to exist is

\[1 \geq \frac{\pi_1^*}{v_1} + \frac{\pi_2^*}{\bar{v}_2} = \beta (\mu^2 + \sigma^2) + \left(1 - \beta \frac{1}{2} \rho(\bar{v}_2)\right)^2. \]  \hspace{1cm} (4.17)
If equation 4.17 does not hold, a peaceful contract is not feasible. This may occur if the players are overconfident, i.e., their combined expected profits are so large that it is not possible to divide the good to sufficiently compensate both players in the first stage. This could, for example, happen if player 2 is very likely to be weak, but is in fact strong. Then, player 1 wants a large share to settle peacefully since she thinks that she is likely to prevail in the contest. But player 2, who is in fact strong, also wants a large share since he knows that even though player 1 now expects to meet a weaker player, he is still the true favorite.

Given that equation 4.17 holds, the more slack there is, the more feasible I define a peaceful contract to be. This is motivated by the fact that the construction of such a contract might come at some fixed cost. By studying equation 4.17 and using the propositions from the previous sections, the effects of new information on the feasibility of a peaceful contract are summarized in proposition 3.

**Proposition 3.** (i) The effect on the feasibility of a peaceful contract of increased variance of the relative resolve is ambiguous since it decreases player 1’s profit and increases player 2’s profit. (ii) If player 1 is the expected favorite, an increase in the mean of the relative resolve always makes a peaceful contract less feasible. If player 1 is the expected underdog, the effect is ambiguous.

*Proof.* Follows directly from equation 4.17 and proposition 1.

It is clear that anything that increases both players’ profits makes a peaceful contract less feasible. Anything that decreases both players’ profits makes a peaceful contract more feasible. Anything that has an asymmetric effect on player 1 and player 2’s profits, respectively, will have an ambiguous effect on the feasibility of a peaceful contract and depend on further parameterization of the model.

In section 4.2, I found that an increase in the variance of the relative resolve always decreases player 1’s profit and increases player 2’s profit. Hence, the total effect of an increased variance of the relative resolve on the feasibility of a peaceful division of the good is ambiguous.

The effect of new information that increases the mean of the relative resolve is to some extent clearer. If player 1 is the expected favorite and new information indicates that player 1 is on average stronger, both player 1
and player 2’s expected profits increase, which makes a peaceful solution less feasible. However, if player 1 is the expected underdog and new information indicates that she faces an on average weaker opponent, players 1’s profit increases while player 2’s profit decreases. This makes the effect on the feasibility of a peaceful solution ambiguous.

To summarize, the only type of new information that is guaranteed to make a peaceful contract more (less) feasible is new information that makes player 2 look stronger (weaker) when player 1 is the expected favorite.

The intuition is the following. Player 1 is always better off with a higher mean of the relative resolve. If player 1 is the expected favorite and she receives new information indicating that she on average faces a weaker opponent, she can relax some of her effort. Since she has a lower effort level but still keeps her (expected) advantage, it makes the contest less costly for her. Regardless of whether player 2 is the true favorite or underdog, he is also better off since he now faces an opponent who exerts less effort. Hence, for both players, a contest is no no longer as daunting which makes a feasible peaceful solution less likely. If, on the other hand, player 1 is the expected underdog, she will increase her effort and expected profit which makes player 2 worse off regardless of type. In this case, there is an ambiguous effect on the feasibility of the peaceful contract.

For a given \( \theta \) that makes equation 4.17 hold, a Perfect Bayesian equilibrium with passive beliefs characterizing a peaceful solution would thus be the following. In the first stage, player 2 is fully informed of his own type and player 1 holds beliefs about player 2’s type given by the commonly known distribution of \( v \). Both player 1 and player 2 accept the contract where \( \theta \) is defined so that both 4.15 and 4.16 hold. Player 1’s beliefs about player 2’s type if she observes the out of equilibrium stage 2 is determined by her prior. Player 1 would thus choose her optimal effort \( x^*_1 \), determined by equation 4.3, in the contest. The optimal response for each type of player 2 is to play his equilibrium strategy \( x^*_2(v) \), determined by equation 4.4.

In a pooling equilibrium, there is in most instances an ambiguous effect on the feasibility of a peaceful contract of new information. A net analysis requires full parameterization of the model. I provide such an example below. First, however, I comment on the conditions for the existence of semi-separating equilibria.

In a semi-separating equilibrium, all types of player 2 with \( v \leq \hat{v} \) accept
the contract and all other types reject the contract. A rejection of the contract by player 2 gives player 1 some information about player 2’s type. If player 1 accepts the contract but is forced to compete in a contest, player 1 knows that player 2’s type is greater than $\hat{v}$. Consequently, player 1 adjusts his optimal strategy in the contest stage according to this new information. Moreover, a player 2 type that rejects the contract knows that her rejection reveals some information to player 1 and takes this into account in the contest. Thus, player 1 solves the following updated problem in case of a contest

$$E[\pi_1] = \int_{\bar{v}}^{\hat{v}} \frac{x_1}{1 + x_2(v)} v_1 dG(v) - x_1 = \int_{\bar{v}}^{\hat{v}} \frac{x_1}{1 + x_2(v)} \bar{v}_1 dG(v) - x_1 \tag{4.18}$$

with $\bar{v}_1 = \frac{\hat{v}_1}{1 - G(\hat{v}_2)}$ and $1 - G(\hat{v}_2)$ is the probability that player 1 will have to enter a contest even though she accepted the contract. This updated contest is then solved analogously to the original contest in section 4.2, resulting in equilibrium profits $\tilde{\pi}_1$ and $\tilde{\pi}_2$. In a semi-separating equilibrium, the participation constraints for player 1 and all types of player 2 must then be

$$G(\hat{v})(1 - \theta)v_1 + (1 - G(\hat{v}))\bar{\pi}_1 \geq \pi^*_1 \tag{4.19}$$

$$\theta v_2 \geq \tilde{\pi}_2 \forall v \leq \hat{v} \tag{4.20}$$

$$\theta v_2 < \tilde{\pi}_2 \forall v > \hat{v} \tag{4.21}$$

where $\pi^*_2$ is the contest profit for a player 2 of a type less than $\hat{v}$ who plays the off equilibrium strategy and engages in a contest.

It is not possible to determine the role of information without an exact parameterization of the distribution of valuations. An increase in the mean of the whole distribution does not necessarily affect the truncated distribution.\footnote{Say, for example, that $v_2$ can take on the values 1, 2, 3 with the respective probability $\frac{1}{3}$, $\frac{1}{3}$ and $\frac{1}{3}$. If only the high value player rejects the contract in a semi-separating equilibrium, player 1 will only focus her attention on that player type if she is forced into a contest. However, decreasing the smallest valuation affects the mean for the whole distribution but not the truncated distribution. The same line of reasoning goes for the truncated probability. If the probability that player 2 is of type 1 and 2 changes to $\frac{1}{2}$ and $\frac{1}{2}$, respectively, this changes the mean but does not change the probability that player 1 will have to enter a contest if she accepts the contract.} Hence, we have to remain agnostic on the effects of an increased
mean and variation of the truncated distribution and the cumulative probability. This could be further studied using exact parameterization. However, the main focus of this study is peaceful contracts and I now return to them by studying explicit examples.

4.4 An example

In this section, I present an analytical example to give some intuition for how the feasibility of a peaceful equilibrium may change with new information. I use a simple distribution where player 2’s valuation can take two different values. Let player 2’s valuation take the value $v$ with probability $q$ and the value $\bar{v}$ with probability $1 - q$. I also relax the assumption $\mu > (1 - \sigma^2)^{1/2}$ to analyze a broader set of outcomes.

Using the results from section 4.2, the equilibrium expected profits in contest are

$$
\begin{align*}
\pi_1^* &= v_1 \beta (q\rho^2 + (1 - q)\bar{\rho}^2) \\
\pi_2^* &= \bar{v}(1 - \beta^{1/2}\bar{\rho})^2 \\
\bar{\pi}_2^* &= \bar{v}(1 - \beta^{1/2}\bar{\rho})^2
\end{align*}
$$

with

$$
\beta = \left( \frac{q\rho^2 + (1 - q)\bar{\rho}^2}{1 + q\rho^2 + (1 - q)\bar{\rho}^2} \right)^2.
$$

A feasible peaceful contract is available whenever the players do not claim shares of the good that sum to more than one i.e., whenever equation 4.17 holds which in this set up is equal to

$$
1 \geq \frac{\pi_1^*}{v_1} + \frac{\bar{\pi}_2^*}{\bar{v}} = \beta (q\rho^2 + (1 - q)\bar{\rho}^2) + (1 - \beta^{1/2}\bar{\rho})^2.
$$

By varying the parameter values in equation 4.22, I can study the effect of new information on the feasibility of a peaceful contract. The importance of expected and true favorites and underdogs for effort and expected profits was made clear in the proposition from HaS and proposition 1. Therefore, I study three different settings, one where player 1 is sometimes the expected favorite, $v < v_1 < \bar{v}$, one where player 1 is always the expected favorite
\( v_1 \leq \underline{v} < \bar{v} \) and finally, one where player 1 is always the expected underdog, \( \underline{v} < \bar{v} \leq v_1 \).

To study new information, I vary \( q \). As for many distributions, changing a parameter has an effect on both the mean and the variance. Therefore, in these examples, it is the joint effect of a changed mean and a changed variance of the relative resolve that is studied. However, when discussing the effect of a changed \( q \), I separate the effect of a changed mean and a changed variance to be consistent with the previous section.

For this distribution, the mean of the relative resolve will be increasing in \( q \). The variance, however, has a maximum for \( q = \frac{1}{2} \). Hence, an increased \( q \) affects player 1’s expected profit negatively through a higher variance for \( 0 \leq q \leq \frac{1}{2} \), positively through a lower variance for \( \frac{1}{2} \leq q \leq 1 \) and positively through a higher mean of the relative resolve for all values of \( q \). It affects player 2’s profit positively through a higher variance for \( 0 \leq q \leq \frac{1}{2} \), and negatively through a lower variance for \( \frac{1}{2} \leq q \leq 1 \). However, the effect of a higher mean depends on player 1 being an expected favorite or underdog. A higher mean of the relative resolve is positive for player 2 if player 1 is the expected favorite and negative if she is the expected underdog.

In the first setting, player 1 can be both the expected favorite and the expected underdog depending on the values of \( q \). Set \( v_1 = 100, \underline{v} = 25 \) and \( \bar{v} = 150 \). Thus, for small values of \( q \), player 1 is the expected underdog while for high values of \( q \), he is the expected favorite. How players’ profits expressed as a share of their valuations and the feasibility of a peaceful solution depend on \( q \) is shown in figure 4.1.

The dotted line is player 1’s profit as a share of her valuation, the dashed line is the high type of player 2’s profit as a share of his valuation and the solid line is the sum of these two. When the sum of the two players’ profit shares is higher than 1, the thick line, a division of the good satisfying both players, becomes impossible (proposition 2). When this happens, one or both players would be better off deviating to the out of equilibrium path, rather than accepting the contract for any division of the good. The distance between the line measuring the sum of both players’ profit shares and 1 is a measurement of the feasibility of a peaceful contract. The larger the distance between the line and 1, the more slack there is in equation 4.17. For values of \( q \) where the line is higher than 1, a peaceful contract is not feasible.

Both \( \frac{\bar{\pi}}{v_1} \) and \( \frac{\bar{\pi}}{v_2} \) are increasing in \( q \). This means that for both players,
the more probable it is that player 1 is facing a weaker opponent (the lower the \( q \)), the less costly a contest becomes. For sufficiently high values of \( q \), there is no division of the good that simultaneously satisfies player 1 and both types of player 2. The variance of the relative resolve is increasing in \( q \) up to \( q = \frac{1}{2} \), making player 1 worse off. However, the mean of the relative resolve is always increasing in \( q \) (player 1 faces a player 2 of the low type with higher probability) which makes player 1 better off. The positive effect of an increased mean of the relative resolve dominates the negative effect of an increased variance. For a high type of player 2, the effect of a higher mean goes in the same direction as a higher variance as long as player 1 is the expected favorite. Both affect player 2’s expected profit positively. For \( q > \frac{1}{2} \) i.e., when the variance is decreasing in \( q \), the positive effect on player 2’s expected profit of an increased mean dominates the negative effect of lower variance. For low values of \( q \), when player 1 is the expected underdog, the positive effect of an increased variance dominates the negative effect of an increased mean.

So why is a peaceful contract not feasible for high values of \( q \)? Intuitively, when \( q \) is high, the likelihood that player 2 is of a low type is also high which means that player 1 will demand a large share of the good since going to a contest does not seem as intimidating. However, if the realization of player 2’s type is high, he also wants a large share of the good. For sufficiently high values of \( q \), the shares that player 1 and the high type of player 2 are
demanding add up to a value above 1, which is impossible to distribute. Hence, a peaceful contract is not feasible.

In the next example, player 1 will be stronger than, or at least as strong as, player 2 in terms of valuations. Set $v_1 = 200$, $\gamma = 50$ and $\bar{v} = 200$. The result is displayed in figure 4.2.

Figure 4.2: Example 2

As in the first setting, a peaceful solution becomes less feasible when $q$ increases. The only qualitative difference from the first example is that a peaceful solution is always feasible. It turns out that for this binary setting, a peaceful solution is always feasible when the high type of player 2 has a lower valuation than player 1. To see this, equation 4.22 can be reduced to

$$
(2 - q)\bar{\rho}^2 + q\rho^2 \leq \frac{2}{\beta^{1/2}\bar{\rho}}.
$$

We know that $\rho < \bar{\rho}$ so 4.23 holds if

$$
(2 - q)\bar{\rho}^2 + q\rho^2 = 2\rho^2 \leq \frac{2}{\beta^{1/2}\bar{\rho}}.
$$

4.24 is guaranteed to hold since $\beta < 1$ ($\bar{\rho} < 1$ since $\bar{v} < v$ was assumed).

In the final example, player 1 is always the expected underdog. I let $v_1 = 100$, $\gamma = 100$ and $\bar{v} = 2000$. The results are displayed in figure 4.3

As previously, Player 1’s profit is increasing in $q$. For $q \leq \frac{1}{2}$, the negative effect on player 1’s profit of an increased variance is dominated by the
positive effect of an increased mean of the relative resolve. However, unlike
the first two examples, the high type of player 2 has an expected profit that
is decreasing in $q$. Player 1 is an expected underdog for all values of $q$. This
means that player 2’s profit is decreasing in the mean for all values of $q$.
This effect dominates the positive effect on player 2’s profit of an increased
variance for $q \leq \frac{1}{2}$. Unlike the first two examples, the feasibility of a peaceful
contract is actually decreasing in $q$ for low values. The negative effect on
the high type of player 2’s profit dominates the positive effect on player 1’s
profit and the contest becomes more costly. However, the net effect switches
as $q$ increases and for sufficiently high values of $q$, a peaceful contract is not
feasible.

It is clear from these examples that it is difficult to say anything in
general about the feasibility of a peaceful contract. To be able to make pre-
dictions, accurate information about the contest structure and the players’
relative valuations is needed. Moreover, comparative statics are dependent
on player characteristics. Some findings are worth emphasizing:

- A peaceful contract is not always feasible. If both players are suffi-
ciently confident to win the contest, their claimed shares of the good
in the bargaining stage will sum to more than one, thus making a
division of the good that satisfies all players impossible (example 1).

- If the valuation of the high type of player 2 is less than player 1’s
valuation, a peaceful contract is always feasible (example 2).

- A strong type of player 2 is not necessarily better off if player 1 believes that he faces a weaker opponent. If player 1 believes that he is the true underdog, player 2 can be worse off if player 1 believes that he is facing a weaker player. Moreover, even though this makes the contest closer, the net effect might be that a peaceful contract becomes more feasible (example 3).

It is straightforward to set up and theoretically analyze these models for different parameter values. However, due to the lack of general comparative statics results, it is difficult to make predictions about similar settings in the real world. It is, however, possible to discuss the different mechanisms in case studies. This is the aim of the next section.

4.5 Discussion

I assumed in the model that the division of the good could be represented by side payments between the players. There is some empirical support for this assumption. The waters in the Norwegian Sea off Lofoten are rich in natural resources. There is, for example, a cod fishery dating back for centuries and a vibrant ecosystem. The waters also hold a lot of oil and gas, some of which is currently extracted. For new oil and gas fields, lobbying is done by petroleum companies arguing for extraction while fishermen are against extraction since they are afraid of the consequences for the marine resources. There is a system of payments to fishermen to compensate for economic losses due to petroleum activities (St. Meld 2010). Another example was the payments from a mining company in the Arctic part of Sweden to homeowners who run the risk of expropriation due to the expanded operations of the mine.

The conflict outside Lofoten is an interesting and appropriate case to discuss using the stylized framework presented in the paper. Define player 1 to be the petroleum companies and player 2 to be their organized opponents (fishermen, tourism). There are estimates of the economic values generated

12 The results do not change qualitatively by using e.g., monetary side payments instead of a divisible good but some details change. For example, assume that side payments are made with a lump-sum transfer from player 1 to player 2. Equation 4.17 would then read

\[ 1 \geq \frac{\pi_1}{v_1} + \frac{\pi_2^e}{v_1}, \]

where \( \pi_2^e \) is the equilibrium profit for player 2 of type \( \bar{e} \).
by both sides but there are large uncertainties about the potential effect of prospecting for, and extraction of, oil and gas on fisheries and tourism. The monetary valuation of the benefits from oil extraction is 105 billion Norwegian kroner while the present values of the profits generated by fisheries are about 25 billion Norwegian kroner (St. Meld 2010). But also non-market values give incentives to exert lobbying efforts. For example, ecosystem values or individual valuations are not quantified and there is also a great deal of uncertainty about these values. The social costs of petroleum extraction are discussed in the official management plan for the Lofoten area and it is stated that: “[t]he figures on which the calculations are based are, however, both incomplete and uncertain. For example, there are no reliable figures on the economics damages on fisheries and aquaculture that a larger accidental discharge may cause” (St. Meld 2010). Still, side payments are used to compensate fishermen to some extent for economic losses, but is it feasible to expand the usage?

It is not unreasonable to assume that due to their economic advantage, the petroleum companies consider themselves to be expected favorites when it comes to lobbying. But the opponents’ valuation is difficult to determine. If the petroleum companies believe the opponents’ valuation to be low with a high probability, they might not be willing to offer large side payments. But if the true value of the opponents’ valuation is sufficiently large, the opponents will not accept a low compensation.

In this setting, consider the impact of a new valuation study trying to also quantify non-market values, such as oil spill risks and consequences. If a valuation study indicates that it is very likely that ecosystem services are of great value, and that fishermen’s and tourists’ valuation of a pristine nature is likely to be high, this would correspond to a decrease in the mean of the relative resolve (the ratio of player 1’s valuation to player 2’s expected valuation decreases). This has a negative effect on both players’ expected profit and thus increases the feasibility of side payments.

The analogous line reasoning also holds for the mining company and homeowners. There are estimates on the value of the reserves of iron ore and the economic values of the homes. However, there are no studies on the sentimental or affective value of homes which homeowners could also demand to be compensated for in case of expropriation. Valuation studies indicating that these values are high could lead to lesser lobbying and a higher
Settlement under the threat of conflict

likelihood that both sides agree on the sufficient level of compensation.

Thus, if petroleum and mining companies underestimate their opponents’ true valuation, this could be one explanation for why side payments have not been used more extensively and why the appropriate level seems difficult to agree upon. If future valuation studies indicate that the true valuation of the opponents is significantly higher than previously thought, side payments is a mechanism through which the probability of fishermen and homeowners being sufficiently compensated is increased and also the risk of inefficient and costly lobbying efforts is reduced.

How side payments are made in practice can differ. Payments are made directly from the mining company to the homeowners in Kiruna, while the state collects taxes and fees from petroleum companies and pays subsidies to fishermen in Lofoten. Compensating for expropriation and risk can thus be quite straightforward even though putting a value on these parameters is a complex process. Compensating for values that are provided to the general public, such as a pristine nature, is less straightforward. How this could be done in practice is debatable. Forcing firms to set aside resources for management of nearby similar areas, or the conservation of parts of prospected areas, could be one option. However, my main point is that these values need to be acknowledged in land use conflicts. The policy implication is that side payments should not only focus on compensation for economic damages but also on compensation for non-market values in order to reduce uncertainty and thus increase the acceptance for side payments as a mean to reduce conflicts over land use.

4.6 Conclusion

In this paper, I assumed two parties to be quarreling over the division of a good. I studied a mechanism which could prevent costly contests similar to settling out of court or the use of side payments between disputing parties. Using a one-sided private information setting, I studied the effect of new information on the feasibility of such a mechanism. I found that such a mechanism is only feasible if the sum of the expected contest profits as shares of the respective parties’ valuations does not exceed one. The sum may exceed one if, for example, the uninformed player believes that the informed player has a valuation much lower than hers while the true valuation of the
informed player is very high. Then, both players would want a large share of the good in order not to engage in a contest, since they would both be confident that they would prevail.

Further, increased uncertainty had an ambiguous effect on the feasibility of a peaceful solution since it made the contest option more attractive for the informed party and less attractive for the uninformed party. I also found that increased average strength of the uninformed player could increase the feasibility of a peaceful solution, if the informed player believes herself to be a true favorite since in this scenario, the change decreases both players’ expected contest profit.

I discussed the model in relation to different contemporary Arctic developments. In northern Sweden, side payments are used to compensate homeowners that are, in practice, expropriated as the operations of a mine are expanded. However, the compensations are solely based on the economic value of the home and many homeowners feel that they are not sufficiently compensated. The other example was the potential use of side payments to fishermen to compensate for economics losses due to petroleum extraction in fishing waters outside Lofoten. This compensatory regime is also based on economic calculations, not involving risk, ecosystem services, or fishermen’s cultural valuations. New non-market valuation studies might provide new information about the true valuations, thus increasing the probability of homeowners and fishermen being appropriately compensated, and hopefully reducing the amount of resources spent on lobbying.
References


4.6. CONCLUSION


A Appendix

A.1 Equilibrium efforts and expected favorites

The first-order condition of equation 4.1 implicitly defines the best response function for player 1. The first-order condition of equation 4.2 gives the best response functions for each type of player 2. The resulting equations are, respectively:

\[
\frac{\partial E[\pi_1]}{\partial x_1} = \int_{\mathbb{V}} \frac{x_2(v)}{(x_1 + x_2(v))^2}v_1dG(v) - 1 = 0 
\]

\[
\frac{\partial E[\pi_2]}{\partial x_2} = \frac{x_1}{(x_1 + x_2)^2}v_2 - 1 = 0 \Rightarrow x_2^*(x_1, v_2) = (x_1v_2)^{1/2} - x_1. 
\]

Using 4.26 in equation 4.25 shows the equilibrium efforts and the equilibrium value of \( \beta \)

\[
\int_{\mathbb{V}} \frac{(x_1v_2)^{1/2} - x_1}{(x_1 + (x_1v_2)^{1/2} - x_1)^2}dG(v)v_1 = 1 
\]

\[
x_1^* = v_1 \left[ \frac{\int_{\mathbb{V}} \rho(v)dG(v)}{1 + \int_{\mathbb{V}} \rho(v)^2dG(v)} \right]^2 = v_1 \left( \frac{\mu}{1 + \mu^2 + \sigma^2} \right)^2 
\]

\[
\Rightarrow \beta = \left( \frac{\mu}{1 + \mu^2 + \sigma^2} \right)^2. 
\]

Having determined the equilibrium efforts, player 1 is the expected favorite if his probability of winning is larger than \( \frac{1}{2} \). Using the equilibrium efforts, we have that \( p(x_1, x_2(v)) > \frac{1}{2} \) is equivalent to

\[
\int_{\mathbb{V}} \frac{v_1\beta}{v_1\beta + v(\beta^{1/2}\rho(v)) - \beta\rho^2(v)}dG(v) > \frac{1}{2} 
\]

\[
\int_{\mathbb{V}} \beta^{1/2}\rho(v)dG(v) > \frac{1}{2} 
\]

\[
2\mu^2 > 1 + \mu^2 + \sigma^2 \Leftrightarrow \mu > (1 + \sigma^2)^{1/2}. 
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