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WORKING PAPER

Why do fishermen comply with regulations?

The role of preferences

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Why do fishermen comply with regulations? The role of preferences

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Abstract

Compliance with rules and regulations is a necessary condition for effective resource management. We investigate how individual attitudes and preferences affect compliance in Norwegian fisheries. We analyze data from a combined web-based experiment and survey of Norwegian fishermen conducted in the spring of 2014. In the economic experiment, the participants won real money in a set of lotteries based on their answers and lottery outcomes. Based on the participants' lottery choices, we derive measures of various individual preferences, including time, risk and social preferences. We combine these preference measures with the fishermen's survey responses related to violations of formal and informal rules, to empirically test and quantify theoretical predictions. Fishermen comply with formal rules primarily because they believe one should obey the law. Our empirical results show that individual preferences matter in how individuals perceive noncompliance, while it matters less for whether one sees oneself as more or less compliant than the average fisherman.

Keywords: Fisheries, Compliance, Preferences, Survey, Machine Learning

JEL Classification Codes: Q22; Q28; K42

1 Introduction

Compliance with rules and regulation is a necessary condition for effective resource management. It is therefore important to improve our understanding of the motivation of resource users to obey or violate certain rules and regulation. Investigating compliance is challenging for two reasons (Boonstra et al., 2016): First, at best, only the number of detected violations can be directly observed, but not the motivation to comply or the temptation to violate. Second, the number of detected violations depend on the probability of being observed, so that any attempts to measure compliance will influence the tendency to comply. Therefore, existing evidence on compliance is often qualitative or stems from self-reported surveys. In spite of these difficulties, this research has consistently and successfully shown how compliance depends on various factors, such as the benefits of a violation, the expected penalty, but also the intrinsic motivation to comply and the social context (Kuperan and Sutinen, 1998; Hatcher and Gordon, 2005; Viteri and Chàvez, 2007; Eggert and Lokina, 2010).

The objective of this paper is to provide quantitative insights on the motivation to comply by analyzing data from a large mail survey conducted among Norwegian fishers. First, we unpack the general notion of compliance by investigating norm-specific motivations and attitudes. In the survey we asked fishers about the perceived severity of various violations, whether it is acceptable in certain circumstances, and whether they violate a regulation more or less of than the average fisher. The survey questions are then combined with data on risk, time, and social preferences that have been obtained from incentivized lottery experiments. The second part of our study therefore analyzes the determinants of compliance, in particular the role of economic preferences.

This paper combines the economic literature on rational compliance (Becker, 1968) and the role of intrinsic motivation and social norms to comply (Acheson and Gardner, 2010; Boonstra et al., 2016). First, the economic literature on compliance is deeply rooted in the work of Gary Becker, who established the idea of a "rational criminal" (Becker, 1968). The idea is that a criminal act is not different than any other economic action, where the expected benefits are weighed against the expected costs. Typically, detection is probabilistic, and hence non-compliance is risky. Hence, the risk preferences are expected to play an important role in determining whether a violation occurs. If the penalty implies an exclusion from the resource grounds (Copeland and Taylor, 2009) or other, potentially reputational costs that occur in the future, time preferences are expected to matter as well. While the theoretical literature predicting non-compliance in fisheries is clear on these factors (for a review, see Nøstbakken, 2008), the empirical literature is very sparse in this respect. In fact, to the best of our knowledge, the two other papers that directly relates compliance and economic preferences are Eggert and Lokina (2010) and Brick et al. (2012).

Eggert and Lokina collect data from artisanal fishers at Lake Victoria, Tanzania, and find that stated measures of risk-aversion are positively related to violations. This

counter-intuitive finding arises most likely because risk aversion is correlated with subsistence fishing. Respondents living at the poverty line may have no other option than to violate existing regulations in order to secure food and income. Brick et al. report the results from a survey in South-African fishing communities. They find a positive correlation between risk aversion and compliance behavior. Here, we conduct an incentivized economic experiment among fishers in a highly developed country (Norway). We contribute to the literature by investigating how elicited time and risk preferences correlate with the tendency to violate rules. In line with theoretical predictions, we find that individuals who are more risk averse, report to violate less.[1]

Overall, however, we find that fishers are rarely motivated by expected penalties, and mostly intrinsically motivated by the universal notion that "one should follow the law." Indeed, while the Becker model is powerful, it falls short of grasping all social complexities of human decision making, in particular the intrinsic motivation and how social norms to comply may be powerful mechanism to deter violations. In principle, these notions are by no means incompatible with a rational actor model, and could enter as potential (psychological) costs of non-compliance.

There are several studies that have followed this approach and that document the importance of non-pecuniary factors such as the perceived legitimacy of the regulations, social interactions with peers, and moral considerations (Kuperan and Sutinen, 1998; Eggert and Ellegård, 2003; Hatcher and Gordon, 2005; Viteri and Chàvez, 2007; Eggert and Lokina, 2010; Jagers et al., 2012). Interestingly, (Eggert and Ellegård, 2003) find a clear difference in the importance of social/moral considerations versus economic consideration depending on the scale of operation in the survey of Swedish fishers: The operators of large, highly capitalized vessels are much less confident that co-management approaches will help to regulate fisheries and put their trust on formal punishment and official monitoring to deter violations. This is in line with findings from Hatcher and Gordon (2005) who survey UK fishers about quota violations and find that non-economic considerations are relatively unimportant in this industrialized fishery.

Clearly, the decision base is typically complex and multi-faceted. As many individuals are thought to be conditionally compliant, the intrinsic motivation to comply will depend on how widespread such behavior is. We therefore add to this literature by exploring how economic preferences (with regard to risk and time) may interact with social value orientation (e.g. altruistic, individualistic).

In addition, we ask individuals about their primary motivation to obey certain rules and regulations. We consider formal violations (e.g. illegal equipment) and informal (norm) violations (e.g. sharing false information). We find that the fear of formal punishment plays only a minor role. Instead, as already mentioned, a main motivation appears

[1]This is also in line with the work of Block and Gerety (1995), who use experiments to study whether there are differences in relative responsiveness to changes in the detection risk and the severity of the punishment between criminals and the general population. Their experimental results confirm that criminals are relatively less sensitive to the detection risk, in line with criminals having relatively low aversion to risk.

to be of deontological nature (i.e. fishers are motivated by the universal rule that one should follow the law). Interestingly, also the development of the stock is an important reason to comply with certain regulations. This is remarkable, given the scale of the Norwegian fisheries where the actions of individual fisher have a negligible impact on the resource base.

With respect to the specific question that we have asked, our survey is closest to the studies of Brick et al. (2012) and Jagers et al. (2012). Brick et al. (2012) study risk preferences and regulatory compliance among South African fishers. As in our case, they use an experiment to elicit risk preferences, and seek to quantify how risk preferences and other fisher characteristics affect reported violations. They find that more risk averse fishers tend to be more compliant. In addition, they find that men and people with fishing rights are less risk averse than women and non-right holding respondents, and consequently, that these sub-groups tend to comply more. Jagers et al. (2012) survey Swedish fishers. In addition to eliciting incentivized measures of preferences, we add to their design by highlighting the rule-specific nature of compliance. Indeed, we uncover strong differences in compliance attitudes and motivations across different types of rules and regulations. For example, we find that only about 10% of the fishers expressed that unreported labor and fishing in the wrong zone / wrong equipment can ever be justified, while about 50% reported that discarding and misreporting can sometimes or even usually be justified.

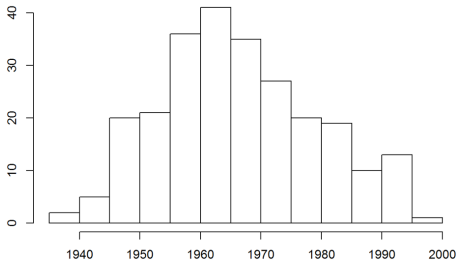
The remainder of the paper is organized as follows. Section 2.1 presents the design of the web-based survey and the experiment. The econometric methods that we employ are spelled out in section 2.2. Section 3 shows the results, while section 4 concludes and briefly discusses our findings.

2 Material and Methods

2.1 Web-based survey and experiment

In order to learn more about compliance behavior and motivations in fisheries, we have conducted a large mail survey among Norwegian fishers. Invitations were sent out in spring 2014 and participants were directed to an online website where they would answer incentivized and non-incentivized choice questions. 253 fishermen responded[2] which is a response rate just above 10%. The respondents represent the entire Norwegian coast, vessel owners and crew, small and large boats, and all age groups (Figure 1). The sample – as the population of Norwegian fishers – consist almost entirely of males (98.4%).

Figure 1: Birth year and geographical distribution of respondents.



(a) Birth year

(b) Location

The survey was made up of three blocks. First, it started with a number of questions on the demographic and socio-economic background of the respondents. We present the results for key characteristics of the respondents in Table 1 while the remaining variables are tabulated in Appendix A.1.

Second, the survey contained a number of lottery-based experiments to measure individual preferences. Specifically, we elicited risk- and time preferences as well as loss aversion by following the methodology that was used by Tanaka et al. (2010) with Vietnamese fishermen. For details about our experiments and the estimation process, see Appendix A.2. Furthermore, we elicited social preferences by using the ring-measure as proposed by Liebrand and McClintock (1988) and used by Voors et al. (2012). The results are shown in Table 2.

The final part of the survey contained fishery specific questions on the fisher's background, the type of fishery they operate in, their investments, and ownership. Importantly, it contained three questions about compliance (or rather, non-compliance).

First, we asked about the fisher's attitude towards various rules and regulations. To

[2]In addition, we elicited answers from a control group of 413 respondents randomly picked from the public registry, but these answers are not used in this paper.

this end, we gave respondents the option to answer "never", "sometimes" or "usually" to the question whether violating a rule or regulation could be justified. Because we were interested whether different types of regulations were perceived in the same way, or whether it is more acceptable to violate some regulations rather than others. We asked this for a range of formal and informal rules and regulations. Specifically, we asked whether it can be justified to (1) employ or offer unreported ("black") labor, (2) use illegal gear, fish outside of the legally mandated seasons or areas, (3) spread wrong information to other fishers, (4) catch fish below minimum size, (5) not report fish sales, (6) discard fish, (7) under- or mis-report catch, and (8) to not share valuable information with other fishers.

Second, for these eight rules and regulations, we asked about the main reason why fishers comply with them. We offered the following choices: "Fear of formal punishment", "One should follow the law", "Stock development and future income", "It is unfair relative to others", "It damages my reputation among fishers", and "other". Clearly, the decision to violate or follow a norm is multi-facetted and several aspects play a role. This is exactly the reason why we have chosen to ask about the *main* reason and allow only one option to be picked. We did not want to impose a ranking ex-post nor would a ranking of the respondents have been very informative as we would have had no possibility to distinguish someone who is almost exclusively deterred by the fear of formal punishment to not discard more fish and also thinks a little bit about the sustainability of the fish stock from someone who is driven by both considerations in about equal terms. Moreover, asking about the main reason to follow a given norm allows us to analyze norm-specific differences in motivations as well as the variability of motivations across and within respondents.

Third, we asked about whether the respondent's think that they violate a given norm "more" or "less" or "about the same" as the average. Here, we have concentrated on the three regulations where we expected the highest degree of violations namely, "discards", "minimum size regulations", and "unreported fish sales".

2.2 Classification

The second aim of our study was to find out what can explain observed compliance motivations and reported behaviors. In other words, we sought to find key underlying determinants of compliance attitudes. As our survey collected a large amount of information about fishermen's characteristics and attitudes, we have a large number of co-variates that could potentially explain whether or not participants responded that they would comply with rules and regulation. Consequently, simply regressing the outcome (compliance, yes or no) on all available predictors would yield an overly good fit for the available data but would probably perform very poorly out-of-sample. Thus, we would like to reduce the variance of our estimates. Moreover, we would like to select the most relevant subset of variables.

In essence, this classification exercise is better suited for modern machine learning

algorithms rather than standard regression analysis. Here, we chose the least absolute shrinkage and selection operator (or simply, the lasso) as method for our analysis.[3]

Consider a dataset with N observations and p predictors. Thus, our co-variate matrix X is of dimension $N \times p$ and our outcome vector y is of length N, with $y_i \in \{0, 1\}$. We assume a logistic distribution of errors, or in other words, that $\Pr(y = 1|X = x) = \frac{e^{\beta_0+\beta^T x}}{1+e^{\beta_0+\beta^T x}}$.[4] The objective of the lasso is to find that vector of estimates $\hat{\beta}^L_\lambda$ that solves:

$$\min_{(\beta_0,\beta)\in\mathbb{R}^{p+1}} - \left[\frac{1}{N}\sum_{i=1}^{N} y_i \cdot (\beta_0 + x_i^T\beta) - \log(1 + e^{(\beta_0+x_i^T\beta)})\right] + \lambda\sum_{j=1}^{p}|\beta_j|. \tag{1}$$

The rightmost term in equation (1) is the penalty function, where λ is a tuning parameter which will be selected by the algorithm. The larger is λ, the larger is the penalty for having a large coefficient estimate. In this sense, lasso "shrinks" the estimates towards zero. Some elements of $\hat{\beta}^L_\lambda$ may in fact set to be exactly zero. It is in this way that the lasso performs variable selection. Conversely, the smaller is λ, the closer is the vector of $\hat{\beta}$ to the vector that minimizes the mean error. Clearly, when λ=0, (1) collapses to the standard logistic regression. In order to select the optimal λ, we span a grid of possible values for λ, and then compute the cross-validation error (the misclassification rate) for each λ and retain that value of λ where the misclassification rate is smallest.

We created binary response variables from the answers to our three questions on compliance attitudes and behavior. Specifically, we analyze whether fishermen state that they violate the discard ban and/or minimum size regulations less than average ($y = 1$) or same/more than average ($y = 0$), and we analyze whether fishermen state that violating discard ban/ minimum size regulations can never be justified ($y = 1$) or whether they state that it can sometimes/usually be justified ($y = 0$). We concentrate on norms and behavior that surround the norm to respect the discard ban and/or minimum size regulations, both because these norms are arguably of key relevance for stock managers and policy makers, and because a full tabulation of all cases would exceed the scope of this paper and exhaust the interest of the reader. The results of this analysis are presented in Section 3.2.1.

To probe deeper into the question of why fishermen comply with these regulations, we analyze whether or not fishermen gave "fear of formal punishment" or "concerns about the future stock development" as opposed to the generic "one should follow the law" as reasons for their behavior. The results of this analysis are presented in Section 3.2.2.

To implement the lasso, we use the package `glmnet`, developed by Friedman et al. (2010), in R version 3.4.0 (2017).

[3]For a good introduction to statistical learning approaches, see James et al. (2013). Lasso, random forests, and other machine learning algorithms are rapidly gaining popularity within economics (Mullainathan and Spiess, 2017) and have been applied to fisheries by e.g. Gutierrez et al. (2011); Sethi et al. (2012).

[4]The log-odds transformation is consequently given by $\log \frac{\Pr(y=1|X=x)}{\Pr(y=0|X=x)} = \beta_0 + \beta^T x$.

3 Results

In this section, we first present the results from the survey by giving an overview of the respondent's characteristics (section 3.1) as well as by exploring their compliance attitudes and norms (subsections 3.1.1-3.1.3). Second, we analyze the determinants of compliance attitudes by presenting the results from the machine learning algorithm (section 3.2.1 and section 3.2.2).

3.1 Respondent's characteristics and compliance attitudes

Table 1 gives summary statistics for key variables of the sample (253 observations) while Table A-1 in the Appendix, gives summary statistics for the remaining numerical variables. In addition we have information on the respondents current place of living, their home community and region, where they were born, and which regulatory group their vessel belongs to.

Table 1

Statistic	Mean	St. Dev.	Min	Max
Age	47.23	12.81	18	77
Gender	0.98	0.12	0	1
NumbKids	2.22	1.60	0	11
NumbSiblings	2.92	1.69	0	11
ParentFisher	0.55	0.50	0	1
ChildrenFisher	0.17	0.38	0	1
Tenure	26.03	14.52	0	64
vesselowner	0.65	0.48	0	1
PersonalIncome	5.32	2.53	0.00	10.00

As can be seen from Table 1, respondents are between 18 and 77 years old and almost exclusively male. They have on average 2.22 children and 2.92 siblings. Interestingly, 55% percent of the fishermen come from families where at least one of the parents have been fishermen, but only 17% think that their children will continue to be fishermen. Those that think that their children will continue to be fishermen, only one had only daughters (while the sex-ratio in children is otherwise approximately equal in the sample). The variable "Tenure" denotes how many years the respondent has already spent in the industry (between 0 and 64 years), the variable "vesselowner" is a dummy which takes on a value of 1 if the respondent owns the vessel he or she is working on, and the variable "PersonalIncome" gives the income bracket for the respondent.

Table 2 shows the elicited risk-, time-, and social preferences. One can see that the fishermen in our sample are comparatively risk tolerant, while the other values are similar to what is reported by Tanaka et al. (2010). The variables "altruistic" and "individualistic" give the social value orientation of the respondents as elicited using the ring measure (where a higher value means a more altruistic/individualistic posture).

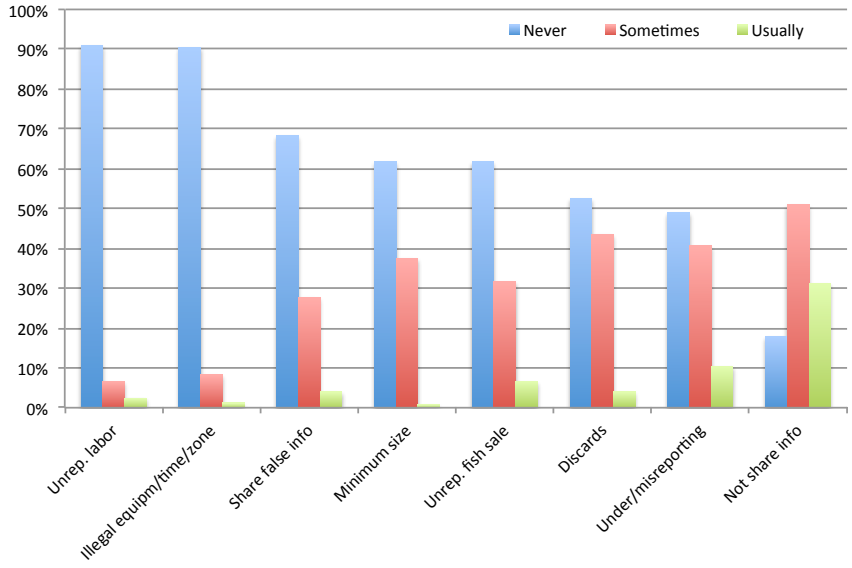
Table 2: Elicited risk-, time-, and social preferences

Statistic	Mean	St. Dev.	Min	Max
r	0.86	0.52	0.05	1.58
α	0.61	0.27	0.08	1.48
λ	2.05	3.09	0.05	11.66
δ	0.11	0.11	0.00	0.29
altruistic	0.10	0.30	−0.72	0.82
individualistic	0.59	0.36	−0.38	1.00

3.1.1 Can it be justified to violate a rule or regulation?

The first compliance related question of the survey was whether it could be justified to violate a rule. We did not, however ask this question generically, but for an array of specific formal regulations and informal norms. Figure 2 shows the relative share of respondents that have, for each rule, answered "never" (blue, leftmost column), "sometimes" (red, middle column) or "usually" (green, rightmost column).

Figure 2: Survey responses to Q1: Can the violation be justified?



Clearly, we see that compliance with rules and regulations is not absolute. Rather, rules and regulations are social constructs that are negotiable and there may be circumstances and reasons when violating a norm can be justified.

Whether it can be justified to violate a given norm depends on the norm itself. This difference is surprisingly large: While 90% of the respondents state that it is never justifiable to violate gear- or area restrictions, more than 50% state that it is sometimes or usually justified to violate reporting regulations.

While we see strong differences between the various norms and regulations, these differences do follow the different classes: While the informal rule that one should not

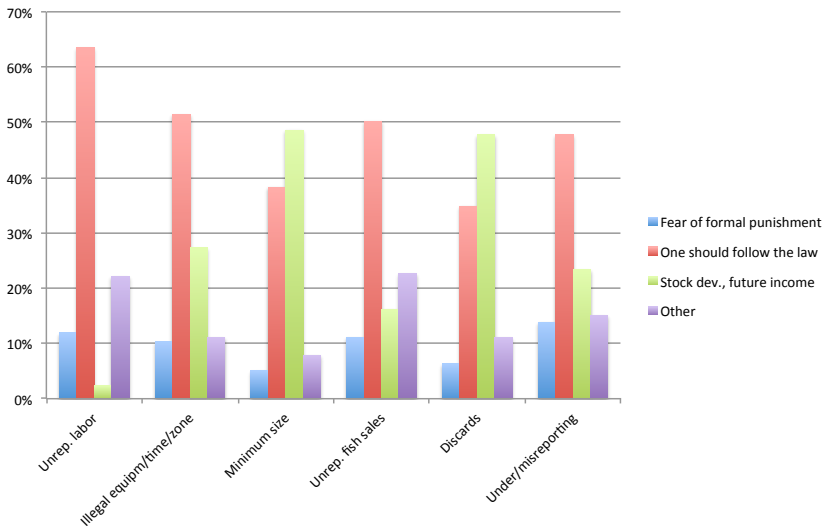
hold back valuable information is the weakest, violations of the corresponding informal norm that one should not spread wrong information is less acceptable than many formal rules. Similarly, the non-fishery specific rule that one should not employ unreported labor is in fact the strongest norm from this set. For the sub-set of formal rules and regulations, the probability to be detected and punished could be a reason for the difference in whether non-compliance is acceptable. Our second question probes deeper into this.

3.1.2 Why comply with rules and regulations?

The stated motivations for why the fishers comply with the various rules and regulations are shown in Figure 3. Maybe surprisingly, the general notion that "one should follow the law" is the main reason for compliance and the second most important reason are considerations about the sustainability of the fishery and the future development of fish stocks. "Fear of formal punishment" (the blue, leftmost bar) is less important and "other" reasons, including concerns about the reputation among fellow fishers play only subordinate role.

Clearly, Figure 3 shows also that the reasons for compliance are norm specific. This is particularly evident for minimum size regulations and the discard ban, which makes sense as violating these rules has the most direct negative effect on the fish stocks. We do not see that fear of formal punishment is systematically lower or higher for those regulations that were most acceptable to violate.

Figure 3: Survey responses to Q2: Main reason for compliance?

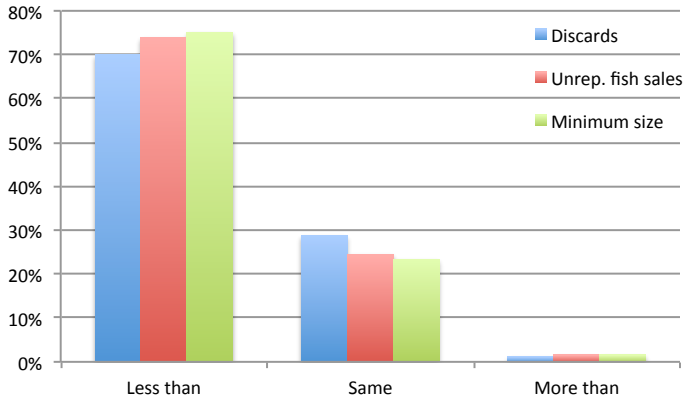


3.1.3 Compliance relative to average?

While it is not possible to obtain direct and reliable information on the actual violations of respondents in a simple survey, we did ask about the compliance behavior relative to the average. Figure 4 shows that the vast majority of respondents think that they violate

less than the average. This is not surprising and reminds of surveys among car drivers where the vast majority of respondents regularly think that they drive better than the average. These effects may be due to over-confidence, an interviewer demand effect, or due to sample selection. After all, those contacted fishers that took the time to respond to our survey may not be representative of the population along unobserved characteristics that correlate with the propensity to follow rules and regulations. However, to the extent that such a selection bias indeed prevails, it does not matter for the analysis here and in the subsequent section, as we are interested in explaining relative differences.

Figure 4: Survey responses to Q3: Assessment of own versus average compliance behavior



We have asked about compliance for only those questions where we expected violations to be most common, namely discards, unreported fish sales, and minimum size regulations. In line with the answers to the question about justifiability of violations (Figure 2), violating the discard ban is most acceptable and has the highest share of respondents that state that they violate this regulation about the same or more than the average.

3.2 Determinants of compliance behavior and attitudes

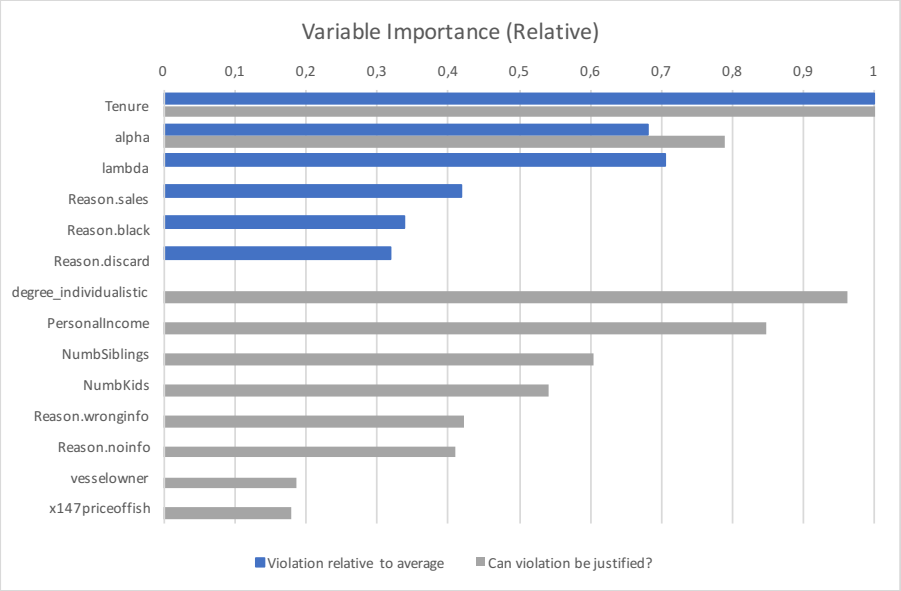
In the following, we present the results which variables explain whether or not respondents state that they violate the discard ban or minimum size regulations less than the average, or that such violations can never be justified. In subsection 3.2.2 we present which variables predict whether or not fishermen gave "fear of formal punishment" or "concerns about the future stock development" as opposed to the generic "one should follow the law" as reasons for why they comply with these regulations.

3.2.1 Violations of the discard ban or minimum size regulations

Figure 5 shows the ranking of the explanatory variables (relative to the variable with the largest decrease in mean Gini index) for the question whether respondents violate the discard ban/ minimum size regulations less than average (blue bars) and whether or not they state that such violations can never be justified (grey bars). In the both cases, "tenure" was the most important variable. Apart from that however, there was little

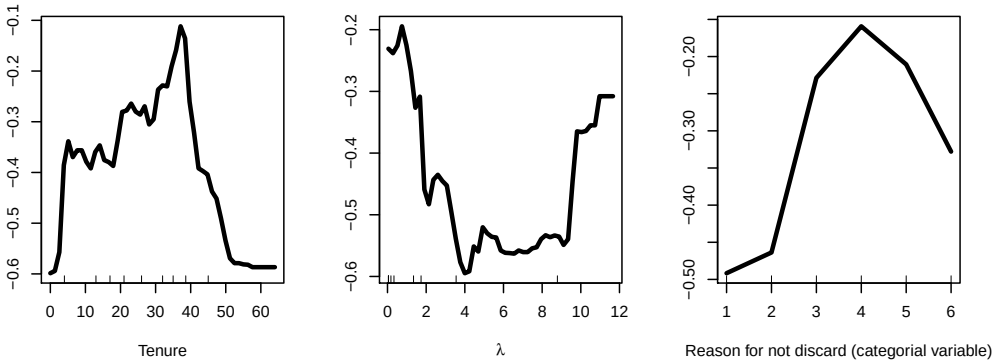
overlap in which variables were retained from the variable selection procedure.

Figure 5: Variable Importance: Violating discard ban/ minimum size regulations less than average (blue bars) and stating that such violations can never be justified (grey bars)



Indeed, the out-of-bag estimate of the classification error rate was rather high in both cases (39% and 34%, respectively), which indicates that a large part of the variation remains idiosyncratic and cannot be well explained by the available co-variates. Figure 6 and 7 show the partial dependence plots for whether respondents state that they violate the discard ban and/or size regulations less than average and, respectively, whether they state that such violations can never be justified.

Figure 6: Partial dependence plots: Violating discard ban/size regulations less than average



With respect to the first question, one can see that propensity to violate less than the average is increasing with tenure (there are very few observations of tenure beyond 40 years, so that the calculated drop visible in the plot should be interpreted with caution). Moreover, one can see that a higher degree of loss aversion (where the mass of observations takes a value between 0 and 2) implies a lower propensity to state that one violates less than the average, but this effects appears to be non-linear. With respect to reason for

not discarding (the right most panel in Figure 6), respondents that gave "future stock development" (category 3) as their main reason are much more likely to violate less than the average than those that give either "fear of formal punishment" (category 1) or "one should follow the law" (category 2) as reasons. The reasons for complying with the discard ban are analyzed in more detail in the next subsection.

Figure 7: Partial dependence plots: Stating that violations of the discard ban/minimum size regulations can never be justified

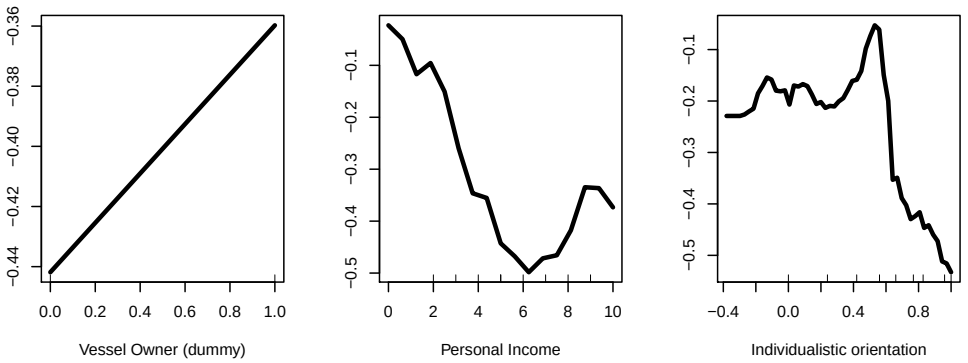


Figure 7 show selected partial dependence plots for the question whether violations of the discard ban and/or minimum size regulations can never be justified. Interestingly, one can see that vessel owners (x=1) are more likely to affirm this than non-owners (x=0). A higher income class (but not a very high income class) has a negative effect on the likelihood of stating that the discard ban and/or minimum size regulations can never. This sheds an interesting light on the correlation between compliance and economic success. Finally, also a more individualistic orientation is correlated with a lower propensity to state that violations can "never" be justified. However, other risk- and time preference play, with the exception of loss aversion, no important role in explaining compliance behavior and attitudes (confer also Figure 5). This stands in contrast to the reasons given for not violating norms and regulations, to which we turn next.

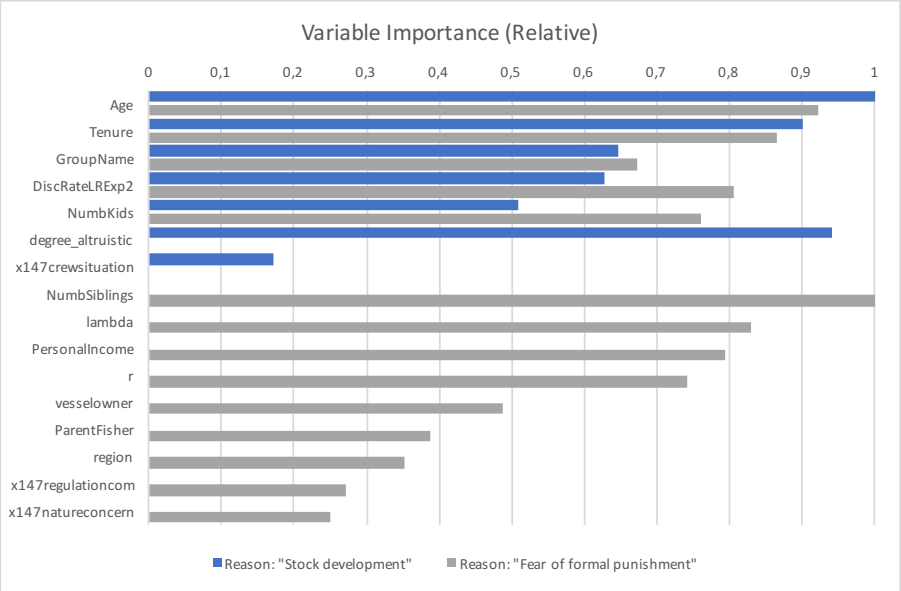
3.2.2 Reasons for compliance with the discard ban or size regulations

Having explored whether respondents state that they violate the discard ban or size regulations, we now investigate why they do not do so. In particular, we study whether they give "future stock development" (y=1) rather than "one should follow the law" (y=0) and we study whether they give "fear of formal punishment" (y=1) rather than "one should follow the law" (y=0). Figure 8 shows which variables are identified as important predictors, with the blue bars referring to the former split of the data ("stock development" versus "follow the law") and the grey bars referring to the latter split of the data ("fear of punishment" versus "follow the law").[5]

Especially when comparing to the actual question of whether or not to comply, we see that the reason given for this question can be explained much more accurately. The set of

[5]Observations that fell in neither category were omitted from the respective analysis.

Figure 8: Variable Importance: Reason for complying with discard regulation is "future stock development" (blue bars) or "fear of formal punishment" (grey bars)



important predicting variables is much more congruent and also the out-of-bag estimate of the classification error rate is lower (15% and 34%, respectively).

While age, tenure, the discount rate, and – curiously – the number of children are important predicting variables in both cases, one can see that the degree of altruism is important in explaining who selects "stock development" but not in explaining who selects "fear of punishment" as reason for compliance. Similarly, the degree of risk aversion r and the degree of loss aversion λ are important in explaining who selects "fear of punishment" but not in explaining who selects "stock development" as reason for compliance. Both facts make, of course, immediate sense. Importantly, they highlight the role of economic preferences for better understanding compliance behavior and attitude.

Figure 9: Partial dependence plots: Giving "stock development" versus "follow the law" as reason for compliance

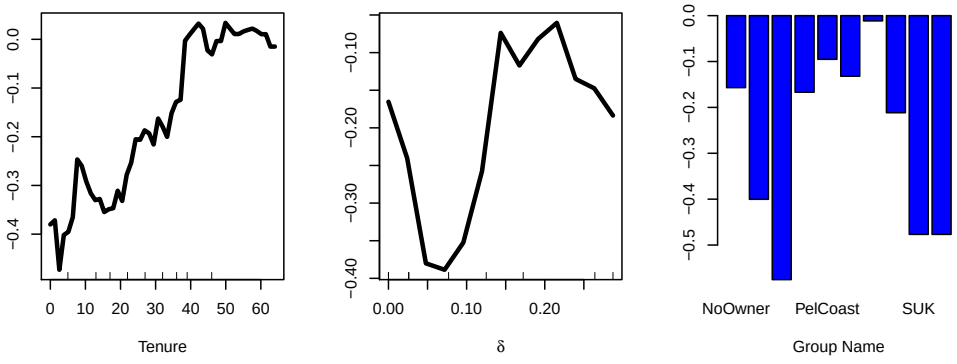
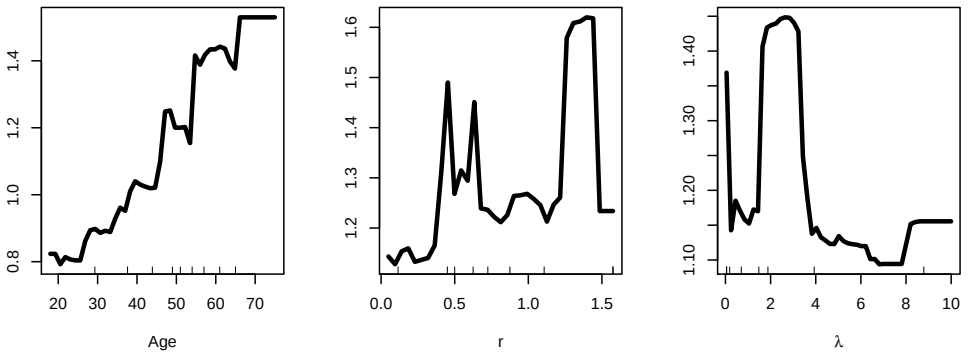


Figure 9 and 10 give the partial dependence plots for selected variables in the two respective question. For the variables tenure and the discount rate δ these plots look very

similar for the two questions and are here plotted for the question "stock development" versus "follow the law" in Figure 9. We see that tenure is positively correlated with the propensity to give "stock development" as reason for compliance. The discount rate δ shows a clear non-linear pattern with respondents that have relatively high or low discount rates are more likely to state "stock development" as reason for compliance. Furthermore, the regulatory group of the fishermen is an important explanatory variable in both cases (also plotted for the question "stock development" versus "follow the law" in Figure 9).

Figure 10: Partial dependence plots: Giving "fear of punishment" versus "follow the law" as reason for compliance



In Figure 10 we show partial dependence plots of age, the risk aversion measure r and the measure of loss aversion λ. Age, which, as tenure, is negatively correlated with choosing "one should follow the law" and shows no sign of non-linearity. This is clearly different for r and λ that both show significant non-linearities. However, these should be interpreted with caution as these predictors are co-variates that we have constructed from the incentivized lottery choices. Overall the data shows that a lower risk aversion or higher loss aversion is correlated with a positive propensity to name "fear of formal punishment" as reason for compliance.

4 Discussion and Conclusion

Globally, about 20 percent of all catches are still caught illegally, making lack of compliance a pressing issue. An open question is how to optimally design enforcement and monitoring schemes. Having observers and video surveillance on board of all fishing vessels is certainly effective, but it will not be cheap and not necessarily efficient. In addition, our study sheds light on the question to what extent formal enforcement interacts with intrinsic motivation or social norms to comply. Interestingly, the theoretical predictions are ambiguous and go in two directions. On the one hand, imperfect monitoring – capitalizing on the intrinsic motivation of most fishers – may backfire if it erodes the motivation to comply, because fishers feel that some "bad apples" get away with violating (Richter and Grasman, 2013; Traxler and Winter, 2012). In such a case, strong regulation would strengthen social norms to comply. However, strong enforcement may also crowd out intrinsic motivation to comply, either because users feel they are mistrusted or because they feel that formal regulations have replaced social norms and they would no longer see it as their responsibility to keep an eye on what fellow fishers do (Ostrom, 2005; Frey, 1997; Bowles, 2008). In such case, formal regulation could crowd out social norms.

Our survey, conducted among Norwegian fishermen, highlighted the prevalence of a strong general notion that one should follow the law as the main reason to comply with regulations. This does not mean that formal enforcement is unimportant. Rather, this conviction must be upheld, both by a functional logic (to protect fish stocks and the future development) and by a confirmation by the regulator via an effective formal enforcement mechanism. Indeed, without such a reinforcing role of the formal management institution, the motivation of fishermen that normally comply may be irreversibly damaged. In the words of (Kuperan and Sutinen, 1998, p. 330): "As moral obligation and social influence are weakened, compliance begins to erode among those who normally would have complied with the regulations. Their subsequent noncompliant behavior influences others not to comply with the regulations, and ultimately compliance breaks down."

Indeed, our survey points out that risk preferences and loss aversion do play a role in explaining compliance decisions, also for those respondents that did not indicate "fear of formal punishment" as the main reason for compliance. Clearly, compliance behavior is complex and determined by several factors simultaneously. Thus, a large fraction of the variation remains specific to the individual. Nevertheless, some patterns emerge clearly in the data.

The second main finding of our survey is that the attitudes and motivations to comply are highly norm specific. With respect to rules that pertain most directly to the health of the resource base, the discard ban and minimum size regulations, the main reason for compliance was indeed the concern about the future sustainability of the fish stock. This was especially pronounced for fishermen that come from the northernmost part of the country. One possible reason for this result could be the specific history of Norwegian fisheries. The stock of the cornerstone species, the Barents Sea cod was severely depleted

throughout the 1970s and 1980s and was perceived to stand at the brink of collapse in 1989. At that time, the Norwegian authorities pulled the emergency break and closed this fishery that was traditionally open to all. Individual quotas were introduced as a short-term fix, and against much opposition. The stock has subsequently recovered and the individual quotas have come to stay. Today, the Barents Sea cod fishery is the one of the most valuable whitefish fisheries in the world. This lesson of "overcoming the cod-crisis" may have had a deep impact and shapes the fisheries discourse in Norway until today.

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Appendix

A.1 Supplementary summary statistics

Table A-1 presents summary statistics on the remaining numerical variables in the dataset that were not shown in Table 1 in the main text. The variable "EduNumb" gives the educational level of the respondents in numbers, where 1 refers to no fulfilled schooling, 2 to fulfilled primary education, 3 to fulfilled secondary education, 4 to a Bachelor degree, 5 to a Master degree and 6 to "No Answer" (only 2 respondents gave no answer, excluding these two numbers yields a mean EduNumb of 3.17). The variables starting with "x147" show dummies on whether or not the given issue (stock development, crew situation etc) was or was not of concern. One can see that most fishermen were concerned about the price of fish, but also about the quota policy and about the development of the fish stocks. The variable "RelativeIncome" compares the income bracket of the respondent to the corresponding income bracket of the mean income in his home community. The variable "Organised" summarizes the elicited info on membership in a dummy which takes on a value of 1 if the respondent is a member in any of the various fishermen organizations. Similarly, the variable "Single" summarizes the elicited information on the marital status and takes on a value of 1 if the respondent is neither married, nor has a co-habitant, nor is in a registered partnership.

Table A-1: Summary statistics for the remaining numerical variables

Statistic	Mean	St. Dev.	Min	Max
EduNumb	3.18	0.98	1	6
x147stockdevelopment	0.38	0.49	0	1
x147crewsituation	0.23	0.42	0	1
x147costdevelopment	0.41	0.49	0	1
x147priceoffish	0.62	0.49	0	1
x147politicuncertainty	0.28	0.45	0	1
x147regulationcomplex	0.23	0.42	0	1
x147natureconcern	0.10	0.30	0	1
x147quotapolicy	0.44	0.50	0	1
x147generational	0.15	0.36	0	1
RelativeIncome	0.61	2.46	−5.79	6.10
Organised	0.52	0.50	0	1
Single	0.20	0.40	0	1

A.2 Measurement of risk, time and loss preferences

The experiments are pairwise-lottery-based experiments in a form that is similar to that of Tanaka et al. (2010) with Vietnamese villagers. We employ a prospect theory framework of Kahneman and Tversky (1979) as opposed to standard expected utility to estimate

respondents' preferences. Consider two mutually exclusive payoff outcomes, x and y, where $x > y$ and $x > 0$. The probability of outcome x is p. We assume agents' values of prospects are $\pi(p)v(x) + [1 - \pi(p)]v(y)$. The function $\pi(\cdot)$ is the probability weighting function. Specifically, following Tanaka et al. (2010), we assume $\pi(\cdot)$ takes the from of one-parameter weighting function that is axiomatically derived by Prelec (1998), i.e., $\pi(p) = e^{-(-\ln(p))^{\alpha}}$. The probability weighting function is linear if $\alpha = 1$ as in standard expected utility theory. The function is S-shaped $\alpha > 1$ (and inverted S-shaped if $\alpha < 1$).

In the prospect value function, $v(\cdot)$ is agents' value of a certain payoff. We assume it takes the form of $v(x) = x^r$ for $x > 0$ and $v(x) = -\lambda(-x)^r$ for $x < 0$. Hence, r is the measure of the concavity of agents' utility function, which is also our measure of agents' degree of risk tolerance. A higher r means the agent is more tolerant to risk. The parameter λ is the measure of loss aversion. A higher λ means the agent is more averse to losses. To sum up, in our measurement process, respondents are assumed to have the following form of values

$$U(x, y; p) = \begin{cases} e^{-(-\ln(p))^{\alpha}} x^r + (1 - e^{-(-\ln(p))^{\alpha}}) y^r, & \text{for } x > y > 0 \\ e^{-(-\ln(p))^{\alpha}} x^r - \lambda(1 - e^{-(-\ln(p))^{\alpha}})(-y)^r, & \text{for } x > 0 > y \end{cases} \tag{A-1}$$

Payoffs used in our experiments are shown in Table A-2. In each experiment, we ask respondents in which situation they would "switch" from lottery A to lottery B. They also have the options to always choose lottery B to lottery A and to never switch from A to B. We jointly estimate r, α and λ using respondents' choices in the first three experiments. The payoffs are carefully designed such that any combination of choices in these three experiments jointly determines a unique set of intervals of the three parameters.

The estimation steps are as follows. First, because the first two experiments do not involve losses, we can jointly estimate r and α using Experiments 1 and 2. For each combination of choices in the first two experiments, (C_1, C_2), we can find a unique combination of value interval of r and value interval of α that will induce a respondent to make such choices. The estimated values of r and α for each combination of choices are shown in Table A-3.

Next, after we have estimated r and α, we can estimate each respondent's value of λ given their choices in Experiment 3. Then we estimate each respondent's discount rate, δ, combining the above estimated parameters and their choices in Experiment 4. While estimating δ, we assume respondents discount their utility rather than cash payoffs.

A.3 Variable Selection for Classification

Figures A-1 to A-4 show the diagnostics from the iterative variable selection procedure.

Table A-2: Four pairwise lottery choices (in Norwegian krones)

Experiment 1					
	Lottery A		Lottery B		Expected payoff diff.
Situations	High (Prob=0.3)	Low (Prob=0.7)	High (Prob=0.1)	Low (Prob=0.9)	(A-B)
1	83	21	141	10	16.5
2	83	21	155	10	15.1
3	83	21	172	10	13.4
4	83	21	193	10	11.3
5	83	21	220	10	8.6
6	83	21	259	10	4.7
7	83	21	311	10	-0.5
8	83	21	383	10	-7.7
9	83	21	456	10	-15
10	83	21	621	10	-31.5
11	83	21	828	10	-52.2
12	83	21	1243	10	-93.7
13	83	21	2071	10	-176.5
14	83	21	3521	10	-321.5
Experiment 2					
	Lottery A		Lottery B		Expected payoff diff.
Situations	High (Prob=0.9)	Low (Prob=0.1)	High (Prob=0.7)	Low (Prob=0.3)	(A-B)
1	83	62	112	10	-0.5
2	83	62	116	10	-3.3
3	83	62	120	10	-6.1
4	83	62	124	10	-8.9
5	83	62	128	10	-11.7
6	83	62	135	10	-16.6
7	83	62	141	10	-20.8
8	83	62	149	10	-26.4
9	83	62	159	10	-33.4
10	83	62	172	10	-42.5
11	83	62	186	10	-52.3
12	83	62	207	10	-67.0
13	83	62	228	10	-81.7
14	83	62	269	10	-110.4
Experiment 3					
	Lottery A		Lottery B		Expected payoff diff
Situations	High (Prob=0.5)	Low (Prob=0.5)	High (Prob=0.5)	Low (Prob=0.5)	(A-B)
1	252	-40	302	-211	60.5
2	40	-40	302	-211	-45.5
3	10	-40	302	-211	-60.5
4	10	-40	302	-161	-85.5
5	10	-81	302	-161	-106
6	10	-81	302	-141	-116
7	10	-81	302	-111	-131
Experiment 4					
	Lottery A		Lottery B		
Situations	Today		8 months later		
1	700		700		
2	688		700		
3	676		700		
4	665		700		
5	654		700		
6	644		700		
7	633		700		
8	624		700		
9	614		700		
10	605		700		
11	596		700		
12	587		700		

Table A-3: Estimates of r and α given all co

r							Exper
Exp.1	1	2	3	4	5	6	7
1	1.575	1.45	1.325	1.3	1.175	1.175	1.05
2	1.475	1.375	1.275	1.225	1.125	1.1	1
3	1.375	1.3	1.225	1.15	1.075	1.025	0.95
4	1.3	1.225	1.15	1.075	1.025	0.975	0.875
5	1.275	1.175	1.075	1.025	0.975	0.9	0.825
6	1.225	1.15	1.075	1	0.95	0.9	0.825
7	1.1	1.025	0.95	0.9	0.85	0.8	0.725
8	1.025	0.95	0.875	0.825	0.775	0.725	0.675
9	0.975	0.9	0.825	0.775	0.725	0.675	0.625
10	0.925	0.85	0.775	0.725	0.675	0.65	0.575
11	0.825	0.775	0.725	0.675	0.625	0.575	0.525
12	0.725	0.7	0.675	0.625	0.575	0.525	0.475
13	0.7	0.65	0.6	0.55	0.5	0.475	0.425
14	0.625	0.575	0.525	0.475	0.45	0.425	0.375
Never	0.575	0.525	0.475	0.425	0.4	0.375	0.325

α							Exper
Exp.1	1	2	3	4	5	6	7
1	0.6	0.575	0.55	0.5	0.475	0.4	0.375
2	0.7	0.65	0.6	0.55	0.525	0.475	0.425
3	0.8	0.725	0.65	0.6	0.575	0.55	0.475
4	0.825	0.775	0.725	0.675	0.625	0.6	0.55
5	0.9	0.825	0.75	0.725	0.675	0.625	0.575
6	0.925	0.85	0.775	0.75	0.7	0.65	0.6
7	1	0.95	0.9	0.825	0.8	0.75	0.7
8	1.05	1	0.95	0.9	0.85	0.825	0.75
9	1.1	1.05	1	0.95	0.9	0.875	0.8
10	1.15	1.1	1.05	1	0.95	0.9	0.85
11	1.2	1.15	1.1	1.05	1	0.975	0.9
12	1.3	1.225	1.15	1.1	1.05	1.025	0.975
13	1.35	1.275	1.2	1.175	1.125	1.075	1.025
14	1.425	1.35	1.275	1.225	1.175	1.125	1.075
Never	1.475	1.4	1.325	1.275	1.225	1.175	1.125

ombinations of choices in Experiments 1 and 2

iment 2 choices							
8	9	10	11	12	13	14	Never
1	0.925	0.875	0.8	0.725	0.675	0.625	0.5
0.95	0.875	0.825	0.75	0.675	0.625	0.575	0.475
0.9	0.825	0.775	0.7	0.625	0.575	0.525	0.45
0.85	0.775	0.725	0.65	0.6	0.525	0.475	0.425
0.8	0.725	0.675	0.6	0.55	0.5	0.45	0.375
0.775	0.725	0.65	0.6	0.55	0.475	0.45	0.375
0.675	0.625	0.575	0.525	0.475	0.425	0.375	0.3
0.625	0.575	0.525	0.475	0.425	0.375	0.325	0.275
0.575	0.525	0.475	0.425	0.375	0.325	0.3	0.225
0.55	0.5	0.45	0.4	0.35	0.3	0.275	0.2
0.475	0.45	0.4	0.35	0.3	0.25	0.225	0.175
0.45	0.4	0.35	0.325	0.275	0.225	0.2	0.15
0.375	0.35	0.3	0.275	0.225	0.175	0.15	0.1
0.35	0.3	0.25	0.225	0.2	0.15	0.1	0.075
0.3	0.25	0.225	0.2	0.15	0.125	0.075	0.05

iment 2 choices							
8	9	10	11	12	13	14	Never
0.35	0.3	0.25	0.2	0.15	0.075	0.075	0.075
0.4	0.35	0.3	0.25	0.225	0.15	0.125	0.1
0.45	0.4	0.35	0.3	0.3	0.225	0.175	0.125
0.5	0.45	0.4	0.375	0.325	0.275	0.25	0.15
0.55	0.5	0.45	0.4	0.35	0.3	0.25	0.2
0.575	0.525	0.475	0.425	0.375	0.35	0.275	0.225
0.675	0.625	0.575	0.5	0.45	0.4	0.375	0.325
0.725	0.675	0.625	0.575	0.525	0.45	0.425	0.35
0.775	0.725	0.675	0.625	0.575	0.525	0.45	0.425
0.8	0.75	0.7	0.65	0.6	0.55	0.5	0.45
0.875	0.8	0.75	0.7	0.675	0.625	0.55	0.475
0.9	0.875	0.825	0.75	0.7	0.65	0.6	0.525
1	0.925	0.875	0.8	0.775	0.7	0.65	0.6
1.025	0.975	0.925	0.85	0.8	0.75	0.725	0.625
1.075	1.025	0.975	0.9	0.85	0.775	0.75	0.65

Figure A-1: Variable Selection Diagnostics: Violating discard ban/ minimum size regulations less than average ($y = 1$) or same/more than average ($y = 0$)

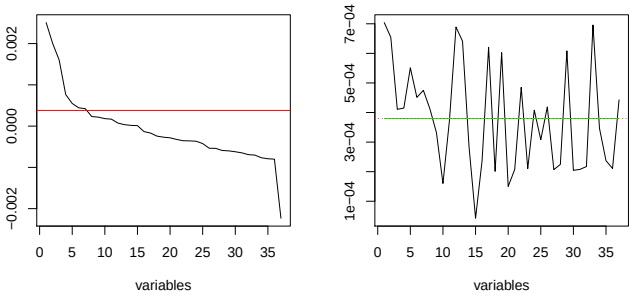


Figure A-2: Variable Selection Diagnostics: Violating discard ban/ minimum size regulations can never be justified ($y = 1$) or sometimes/usually be justified ($y = 0$)

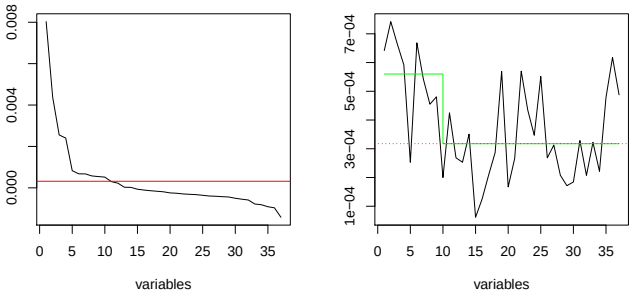


Figure A-3: Variable Selection Diagnostics: Reason for not violating discard ban is "stock development" ($y = 1$) rather than "one should follow the law" ($y = 0$)

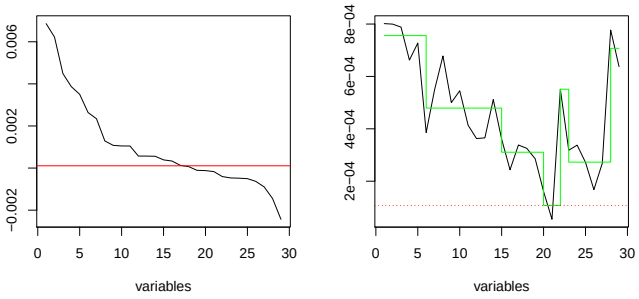
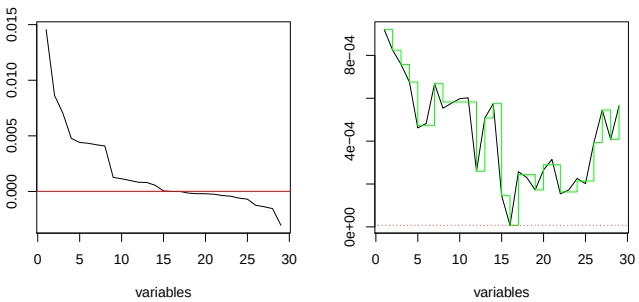


Figure A-4: Variable Selection Diagnostics: Reason for not violating discard ban is "fear of formal punishment" ($y = 1$) rather than "one should follow the law" ($y = 0$)



Compliance with rules and regulations is a necessary condition for effective resource management. We investigate how individual attitudes and preferences affect compliance in Norwegian fisheries. We analyze data from a combined web-based experiment and survey of Norwegian fishermen conducted in the spring of 2014. In the economic experiment, the participants won real money in a set of lotteries based on their answers and lottery outcomes. Based on the participants` lottery choices, we derive measures of various individual preferences, including time, risk and social preferences. We combine these preference measures with the fishermen`s survey responses related to violations of formal and informal rules, to empirically test and quantify theoretical predictions. Fishermen comply with formal rules primarily because they believe one should obey the law. Our empirical results show that individual preferences matter in how individuals perceive noncompliance, while it matters less for whether one sees oneself as more or less compliant than the average fisherman.

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