Further Investigations into the Factors Affecting Compliance with UK Fishing Quotas

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Abstract

This paper reports the results of a more recent study of quota compliance in the UK fishery investigated in Hatcher et al. (2000). The new study collected more detailed data on fishermen’s perceptions and experience of enforcement and sought to measure the financial incentive to cheat. In addition, whereas the earlier study used a binary approach to modelling the data, in this study we employed an ordered response model and included a number of scale regressors without transformation. Although we still find some evidence of normative influences on violation levels, the results suggest that “conventional” economic incentives and disincentives predominate in the fishery.
1 INTRODUCTION

In an earlier study reported in this journal (Hatcher et al. 2000), an empirical investigation into the factors affecting UK fishermen’s compliance with quotas found certain personal normative and social influences to be significant in the determination of compliance/violation decisions, alongside various factors associated with the enforcement process. The present paper describes the results of a second, more recent, study focusing on quota compliance in the same UK fishery. Methodologically, the new study differs in two important respects. First, the field survey we conducted investigated in more depth fishermen’s perceptions about, and experience of, enforcement, and in addition attempted to measure factors associated with the financial incentive to violate quota limits. Second, whereas the earlier study used a binary probit model with mainly indicator (dummy) variables on the RHS in order to estimate the determinants of violation, here we employ an ordered probit model and include on the RHS a number of scale (ordinal) variables. The econometric considerations which underpin the model specification are discussed in the paper. The results of this, we believe, richer approach to the modelling of predominantly categorical data are rather different from those of the earlier study and suggest the overriding importance of “conventional” economic incentives and disincentives in the study fishery, at least at the present time.

Still relatively few studies have modelled empirically the determinants of regulatory compliance in fisheries. Early studies by Sutinen and Gauvin (1989) and Furlong (1991) focused primarily on the monetary costs and benefits of the compliance/violation decision, following a utilitarian model of fishermen’s behaviour due to the economics of crime literature (see Becker 1968, Ehrlich 1972, 1973, Block and Heineke 1975). Subsequently, a seminal conference paper by Sutinen and Kuperan (1995, 1999) drew on theories and empirical work from sociology and social psychology to propose an extended model which included the influence of personal (moral) norms, social
norms and instruments, as well as perceptions of regulatory legitimacy, on individual compliance behaviour.\(^1\) This was accompanied by a paper reporting the results of an empirical study into the factors affecting compliance with zoning regulations in a Malaysian fishery (Kuperan and Sutinen 1995, 1998) which found evidence that normative and social factors had an important influence on levels of violation. Hatcher et al. (2000) employed a similar approach to investigating compliance with quotas in the UK, concluding there was evidence that compliance with fishery regulations in a large-scale, developed country fishery was also determined in part by normative and social influences. Specifically, these authors found that compliance with quotas was positively associated with a personal norm of fair shares, the perception of compliance by other local fisherman, and a feeling of personal involvement in the quota management system. The feeling of involvement in the management system was taken to express a judgement about the legitimacy of the system. The idea that compliance in fisheries is closely linked to regulatory legitimacy, and in particular to the involvement of fishermen in regulatory institutions such as “co-management” systems, is enduring in the fisheries social science literature (see, for example, Jentoft 1989, Pinkerton 1989, Nielsen 1994, Jentoft and McCay 1995, Ostrom 1995, Nielsen and Vedsmund 1997, Hanna 1999, Nielsen and Mathiesen 2003). While the notion is intuitively appealing, the empirical evidence for this association is generally weak. The finding that an index of involvement was significant in an econometric model of compliance, however, appeared to support a link between co-management, regulatory legitimacy and compliance.

Theoretical and empirical arguments for a more complete model of violation behaviour incorporating normative and social factors are discussed in some detail by Sutinen and Kuperan (1999) and Hatcher et al. (2000). In general, we take a neo-classical utilitarian model of individual violation behaviour of the form

\[
V_i = f (I_i, D_i, X_i),
\]  

(1)

\(^1\) An earlier discussion of the role of non-monetary factors in fisheries violations could be found in Sutinen, Rieser and Gauvin (1990).
where the individual’s violation rate, or supply of violations, \( V_i \) is a function of variables related to financial incentives to violate \( I_i \), deterrents to violation \( D_i \) and measurable personal characteristics \( X_i \), such as age, experience, and so on, and expand it to

\[
V_i = f(I_i, D_i, M_i, S_i, L_i, X_i),
\]

(2)

where \( M_i \) is a set of variables related to personal normative (“moral”) judgements about violation, \( S_i \) is a set of variables related to the perceived behaviour and opinions of significant others, i.e., social influences, and \( L_i \) is a set of more or less normative judgements about the legitimacy of the regulatory system, including the regulations themselves as well as the regulatory institutions and processes.

A theoretical model representative of the general form shown in (1) and applicable to continuous choice over a decision variable which is legal over some range and illegal above a certain threshold, such as a vessel’s catch in the presence of a catch quota, is an expected utility of profit function of the form

\[
EU \{ \pi(q) \} = PU \{ B(q) - F(q) \} + [1 - P] U \{ B(q) \},
\]

(3)

where a benefit function \( B(q) \) is associated with a level of catch \( q \) and a fine \( F(q) \) is incurred for levels of catch in excess of a quota \( Q \), with the probability of being detected in violation and hence incurring a fine denoted by \( P. \)

Assuming an interior solution, the necessary first-order condition for an expected utility maximising solution to the choice of \( q \) is \( dEU \{ \pi(q^*) \}/dq = 0 \) and hence

\[
B'(q^*) = \frac{PF'(q^*) \cdot U' \{ B(q^*) - F(q^*) \}}{PU' \{ B(q^*) - F(q^*) \} + [1 - P] U' \{ B(q^*) \}}.
\]

(4)

While this appears complex, note that the expression collapses to

\[
B'(q^*) = PF'(q^*),
\]

(5)

more recognisable as the equality of marginal benefit and (expected) marginal loss, in the case

\(^2\) For clarity, individual subscripts have been omitted from the notation.
of a constant marginal utility of income $U'\{\cdot\}$, or, equivalently here, if we simply maximised expected profit instead of utility of profit.

The key policy prescriptions to emerge from this type of model relate to the optimal probability of detection and sanction, which depends upon enforcement effort, and the optimal size of the penalty. Since the expected penalty is a product of the (subjective) probability of detection and sanction and the penalty if sanctioned, and since enforcement is usually costly, the general conclusion is that deterrence should as far as possible be achieved by increasing the size of the penalty (Polinsky and Shavell 1979, 1992, Shavell 1993). Ehrlich (1973) examined the possibility that $P$ was related not only to known parameters of the enforcement system, but also to the amount of time spent by an individual in illegal activity, i.e., habitual offenders have a biased assessment of their risk of getting caught. Thus habitual offenders may have a lower assessment of the risk of detection, for example because they have developed techniques for avoiding detection, or because they have been lucky enough to avoid detection in the past. Alternatively, it is plausible that persistent offenders might have a higher assessment of their risk of getting caught, because they know that enforcement is being targeted at them, or perhaps because they think their luck may be running out. Furthermore, in many enforcement schemes it is likely that the probability of both detection and sanction will increase as the size of violations increases: larger violations are more likely to be discovered and are more likely to attract prosecution. The likelihood that the subjective probability of detection is related to the frequency and/or size of violations has an important bearing on the estimation of empirical models of violation decisions, as we discuss later in the paper.

It is possible to develop a theoretical continuous choice model similar to (3) which incorporates normative judgements about violation behaviour. In Hatcher et al. (2000) a simple “utility adjusting” model is envisaged in which the utility derived from the rewards of violation is
diminished if there are normative or social judgements against violation. This idea follows from models proposed by Dowell, Goldfarb and Griffith (1998) in which behaviour perceived as immoral results in a shift in the utility derived from any goods obtained from that behaviour.\(^3\)

Consider, for example, the effect of a moral judgement about exceeding a catch quota on the utility of the expected profit derived from the quota violation. Letting \(EV\{\pi(q)\}\) be the “morally adjusted” expected utility of profits, suppose we have

\[
EV\{\pi(q)\} \equiv m(q) \cdot EU\{\pi(q)\},
\]

where \(m(q) \in [0, 1]\) represents the influence of a moral judgement on the choice of \(q\), with \(m(q)\) weakly decreasing in \(q\). By the product rule, the necessary first order condition for an optimal solution to (6) is

\[
\frac{dm(q^*)}{dq} \cdot EU\{\pi(q^*)\} + \frac{dEU\{\pi(q^*)\}}{dq} \cdot m(q^*) = 0.
\]

If no feasible choice of \(q > Q\) is regarded as at all immoral, then for any \(q\) we have \(m(q) = 1\) and \(dm(q)/dq = 0\) and (7) becomes

\[
\frac{dEU\{\pi(q^*)\}}{dq} = 0,
\]

which is the same as the decision rule for a strictly rational agent. If any \(q > Q\) is regarded as so immoral that it is not chosen, then we have \(q = Q\) by assumption. Otherwise, \(q\) is increased until condition (7) holds, at which point we have

\[
\frac{dm(q^*)}{dq} \cdot EU\{\pi(q^*)\} = -\frac{dEU\{\pi(q^*)\}}{dq} \cdot m(q^*) < 0,
\]

where \(0 < m(q^*) < 1\) and hence \(0 < EV\{\pi(q^*)\} < EU\{\pi(q^*)\}\). If we assume that the shape of the function \(m(q)\) is determined by some underlying moral (normative) belief or value parameter \(M\), so that for any \(q^*\) we have \(dm(q^*)/dM < 0\), then using the Envelope Theorem \(dEV\{\pi(q^*)\}/dM < 0\) and hence \(\partial q^*/\partial M < 0\). Thus the extent of violation is negatively related to the strength of moral judgement (\(M\)) against violating, which is the hypothesis advanced in Sutinen and Kuperan (1999) and Hatcher et al. (2000). The effects of social influence, and of

\(^3\) As these authors note, the models are formally similar to the concept of “state-dependent” utility in the literature on risk and uncertainty (see, for example, Hirschleifer and Riley 1992).
judgements about regulatory legitimacy, can be thought of in a similar way.

In this study we therefore aim to estimate a general supply of violations function of the form shown in (2), where we can test the following hypotheses for the \( j \)th variables in each of the variable vectors identified:

\[
\frac{\partial V_i}{\partial I_{ij}} > 0, \quad \frac{\partial V_i}{\partial D_{ij}} < 0, \quad \frac{\partial V_i}{\partial M_{ij}} < 0, \quad \frac{\partial V_i}{\partial S_{ij}} < 0, \quad \frac{\partial V_i}{\partial L_{ij}} < 0, \quad (10)
\]

assuming that higher measurements of \( M_{ij}, S_{ij} \) and \( L_{ij} \) correspond, respectively, to stronger moral (personal normative) judgements against violation, perceptions of stronger social norms against violation, and increasingly positive judgements concerning the legitimacy of regulations and of the regulating authorities.

In describing the results of our recent study of UK fishermen’s compliance with fish quotas, the paper proceeds as follows. The next section describes the survey and presents an overview of the survey results. Section 3 then outlines the modelling approach and reports the results of the econometric model. Section 4 discusses the results and makes some concluding comments.

2 SURVEY DESCRIPTION AND RESULTS

As a member of the European Union, the United Kingdom manages its sea fisheries under the provisions of the EU’s Common Fisheries Policy, which include the requirement to observe annual catch quotas for most commercially important fish stocks. Within the UK, responsibility for managing the allocation and uptake of national quotas is substantially devolved to the fish producers’ organisations (POs) to which the majority of the UK’s offshore (over 10 metre) fishing vessels belong.\(^4\) Annual quota allocations to the now 20 UK POs depend upon notional fixed quota entitlements held by each of the over 10 metre vessels in their membership. The

\(^4\) Officially recognised POs under CFP rules were originally intended to play a key role in the organisation of fish marketing, but in some EU member states, the UK in particular, they have assumed primarily a fishery management function.
subsequent internal allocation of quota amongst the membership, however, is decided by the POs themselves. Historically, many of the POs pooled their quota and set monthly quota limits to apply to all member vessels, but in recent years more POs have adopted individual quota systems, at least for some stocks, or have allowed their members to increase their monthly allowances by leasing in quota on an individual basis. Although the UK does not have an ITQ (individual transferable quota) system as such, relaxed provisions for the in-year exchange of quota between POs has allowed an active quota market to develop, particularly for the short-term leasing of quota. With the exception of boats targeting non-quota species (such as crab and lobster), very few over 10 metre vessels remain outside PO membership and these are allocated monthly quota limits directly by the Government Fisheries Departments. Fishing vessels of 10 metres or under in length are not, in most circumstances, subject to any individual quota controls.

Enforcement of quotas depends principally upon verification of the accuracy of catch logbooks kept at sea and of the landings declarations which must be submitted at the time of landing. Vessel boardings and inspections at sea and landings inspections are the responsibility of various agencies, depending on the particular part of the UK, with infringements leading to successful prosecution attracting financial penalties which are largely at the discretion of the Courts. Although the POs have internal disciplinary procedures to deal with any quota overruns which come to their attention, they do not have an explicit enforcement role and rely principally on copies of their members’ logsheets and landings declarations for monitoring quota uptake (the

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5 Recent accounts of the development and operation of the rather complex UK quota management system can be found in Hatcher and Read (2001) and Hatcher et al. (2002); see also Hatcher (1997).

6 The task of enforcing the requirements of EU legislation for vessels to keep true logsheets and to submit accurate landings declarations falls to officers of the Sea Fisheries Inspectorate (in England and Wales), the Fisheries Inspectorate of the Department of Agriculture and Rural Development for Northern Ireland and the Scottish Fishery Protection Agency. Enforcement at sea around England and Wales is currently undertaken by the Royal Navy Fishery Protection Squadron on behalf of the Sea Fisheries Inspectorate. Offences may be referred to the Courts in which case the statutory maximum fine is £50,000 (plus costs and all or part of the value of the catch).
POs do not themselves undertake inspections in order to verify the accuracy of the paperwork. A vessel deliberately seeking to land significant quantities of over-quota fish will therefore falsify its documentation in order to appear in compliance with its PO’s quota management rules, and hence with relevant national and EU legislation. From the few independent studies available, it appears that the frequency of landings inspections, and the levels of penalties imposed by the Courts, may be insufficient to ensure adequate compliance with quotas (for example, NAO 2003).

The present survey was undertaken early in 2002. In the survey region (which, as before, is not identified) there were an estimated 214 over 10 metre vessels targeting quota stocks and a sample of 72 (one third) of these vessels were included in the survey. The sample was selected at random within strata for PO membership, vessel size and fishing method and included 34 members of each of the two main POs based in the region and 4 independent vessels. Most of the vessels were trawlers and gill netters of various designs ranging from just over 10 metres to 33 metres in length (mean 19 metres).

The basic approach to data collection followed that employed by Hatcher et al. (2000). Structured questionnaires were designed to record respondents’ recollections, estimations and perceptions regarding levels of violation of quota limits; the probabilities of detection if violating and of sanction if detected; the expected fine if sanctioned; experience of enforcement events and convictions; financial incentives to violate quota limits; social factors potentially influencing violation decisions; personal moral judgements about violation and compliance; and the perceived legitimacy of the quota management system. The latter was explored through a number of questions seeking respondents’ views on the effectiveness of quotas, the fairness of the quota allocation system, the effectiveness and fairness of enforcement, the rights of authorities at different levels to impose quota controls, as well as the involvement of the fishing industry and the
respondent himself in the quota management process. All these data were recorded as points on appropriate scales, i.e., as ordered categorical data. In a number of the questions concerning judgements about the management system, Lickert-type scales were used to measure agreement with a given normative statement. Descriptive data about the skipper and his vessel were recorded either directly (in the case of age and experience, for example) or, where appropriate, using an interval scale (vessel gross earnings).

The questionnaire was administered in face-to-face interviews with the skippers of the vessels in the sample, giving assurances of individual anonymity and confidentiality. Considerable care was taken in the design of the questionnaire and its administration in order to maximise the likelihood of honest responses, in particular regarding questions about own violation behaviour. Just two respondents refused to answer questions about their quota violations, giving a final usable sample size of 70. The mean age of the skippers interviewed was just over 46 years (range 27-71 years) with a mean of around 30 years experience in fishing (range 10-50 years). The majority (60) were the sole owners of their vessels. Gross earnings in the previous year ranged from under £50k to over £550k.

Only 14 respondents (20%) claimed not to have landed any over-quota fish in the previous year, while just over half the sample said that they had exceeded their quotas by up to 10% and over a quarter (27%) estimated that they had exceeded their quotas by around 20% or more. Just 8 respondents said that their quotas did not significantly restrict the potential earnings of their vessel, while nearly a quarter estimated that quotas restricted their vessel’s earnings by 10% and nearly as many again put the restriction at around 20%. Over a quarter considered

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7 The approach to investigating regulatory legitimacy is based on the classic “Chicago” study of compliance with the law by the sociologist Tom Tyler (Tyler 1990). Key determinants of legitimacy are identified as effectiveness and fairness in relation to both the process and the outcome of regulation, in addition to more direct judgements about rights to impose regulations and feelings of involvement in, or exclusion from, regulatory institutions.

8 See, for example, Fink (1992). Following Long (1997), the ambiguous mid-point (“neither agree nor disagree”) was omitted in all cases.
that their earnings would be restricted by 30% or more if they complied fully with their quotas. Only 10% of respondents thought their vessel could comfortably remain viable if they complied. Nearly two-thirds of the sample leased in extra quota above their basic entitlement.

Considering their experience of enforcement, half the sample reported that their vessel had been boarded two or three times in the previous year, just over 10% had not been boarded at all, while over a third had been boarded 4 times or more. More than half of all respondents had had their landings inspected 4 or more times in the previous year. Within the last ten years, almost a quarter of the sample had been successfully convicted on one occasion of landing over-quota fish and 9 individuals (13%) had received two or more such convictions.

Just over a third of respondents considered that if they were to land over-quota fish their chances of getting caught were “very high”, while 16% (11) thought they were “reasonably high”. On the other hand, 25 respondents (36%) thought the probability of detection was either “very low” or “moderately low”. A little under half of the sample considered that offenders were always prosecuted and a quarter thought this was usually the case, while 14% (10) thought that offenders were only sometimes prosecuted. Many respondents did not feel able to estimate an expected fine, however, presumably because the scale of the offence is likely to have a considerable impact on the actual penalty imposed.

Further views on enforcement were obtained through explorations of the perceived legitimacy of the quota management system. Most of those interviewed (over 80%) thought that fishery officers and inspectors were either “quite fair” or “very fair” in their decisions to inspect particular vessels, but a significant minority considered the pattern of inspections to be unfair. Over three-quarters of respondents considered that boardings and logbook checks at sea were “sufficiently frequent” for quota enforcement, while 87% thought the same for landings inspections.

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9 Indicative percentage probabilities were attached to these levels in the question put to respondents.
in port. Nearly three-quarters of the sample thought that fines were generally high enough to deter over-quota landings.

Asked about the effectiveness of quotas, while just 10% of those sampled agreed that quotas were effective in conserving stocks, nearly a third agreed that they would be effective if fishermen complied with them. Only around 20%, however, agreed with a normative view that quotas should be complied with because they were “necessary to conserve fish stocks”.

Nearly all respondents thought the EU was unfair in its international allocation of total allowable catches (TACs), but more than half thought that the UK system of quota allocation was generally fair. While some two-thirds of the sample considered their own quotas either “slightly unfair” or “very unfair”, many apparently judged this in relation to foreign vessels rather than to other UK vessels. More than half the sample thought that the EU, rather than the UK Government, was primarily responsible for the fact that they faced quota restrictions, and over 85% did not agree that the EU had the right to impose quotas. Just over half, however, agreed that the UK had a duty to impose quotas as a member of the EU (this may, of course, have been an acknowledgement of fact more than a normative judgement). Some two-thirds of the 66 PO members in the sample agreed that “quotas should be complied with because they are rules made by your PO”.

With regard to perceptions of involvement in management, just over a third of respondents considered that the UK fishing industry as a whole was either “quite involved or “very involved” in the design and operation of the quota management system, while 17% thought the industry was “actively ignored”. In the case of their own personal involvement, on the other hand, rather more (almost a half) felt either “not involved” or “actively ignored” in the system.

Considering personal (normative) attitudes to compliance, just over half the sample agreed that
“quotas should be complied with because they are the law” but around three-quarters disagreed that “quotas should be complied with because otherwise you are taking more than your fair share”.

Turning to our explorations of social influence, opinions were divided about the behaviour of others in the respondents’ peer groups (i.e., the same PO or other local vessels). While just over half thought that most or all complied most of the time, a quarter considered that many or most of their peers regularly landed over-quota fish. More than 80% of respondents considered that other local fishermen would know about it if they landed over-quota fish. However, over 90% thought that this would make no difference to others’ opinion of them. Asked about the perceived compliance behaviour of fishermen throughout the region as a whole, around a third of respondents considered that “just a few” regularly landed over-quota fish while over 40% thought that many or most did. This last figure increased to over 60% with reference to fishermen from other parts of the UK, and to around 95% for foreign vessels and “quota-hoppers” (UK-flagged vessels under foreign ownership).

3 MODEL ESTIMATION

Here we define the specific variables used in estimation, describe some measurement problems and report empirical results and hypothesis testing. In estimating the model there were a number of econometric issues to be addressed. First, the dependent variable for the Violations equation is measured as an ordered categorical variable and standard Least Squares regression procedures are therefore inappropriate (Long 1997). The appropriate ordered maximum likelihood procedure (an Ordered Response Model) associates probabilities with each category based on information in the data set and can predict changes in probability with respect to each regressor variable. This procedure is well developed in the economics literature and is
applied here (e.g., Wooldridge 2002, Greene 2003). There also exists the possibility of endogeneity in a regressor variable. Specifically, as discussed in the first section, we hypothesise that fishermen may judge their perceived probability of detection on the basis of their pattern of violations. If the violation rate and the subjective probability of detection are jointly or simultaneously determined in our Violations equation then standard estimation procedures will result in inconsistent parameter estimates. This problem can be tested using a transformation of the Hausman-Wu procedure, as described by Rivers and Vong (1988). In anticipation of the results (reported later in this section) we found that endogeneity was not a serious statistical problem in this case, which allowed a single equation model for Violations to be estimated.

For the Violations equation we can think of the dependent variable as a latent variable that describes the degree to which fishermen are in violation of their quotas. A measure of violation was captured in the survey as the respondent’s estimated percentage of landings over quota in the previous year, with responses in six ordered intervals from 0% over quota to 30% over quota or more. Let $V^*$ represent the latent variable for violation and $V$ the measured intervals. The relationship between the latent and measured variables is then

\[
V = 1 \quad \text{if} \quad -\infty \leq V^* \leq \mu_1,
\]

\[
V = 2 \quad \text{if} \quad \mu_1 \leq V^* \leq \mu_2,
\]

\[
\vdots
\]

\[
V = 6 \quad \text{if} \quad \mu_5 \leq V^* \leq \infty.
\]

---

10 The software used was Stata 7 for Windows (Stata Corporation); see Long and Freese 2001.
We assume that the latent variable can be described by a normal distribution, so that

\[
\begin{align*}
\Pr (V = 1) &= \Phi (-\beta^T X), \\
\Pr (V = 2) &= \Phi (\mu_1 - \beta^T X) - \Phi (-\beta^T X), \\
\vdots & \\
\Pr (V = 6) &= 1 - \Phi (\mu_5 - \beta^T X),
\end{align*}
\] (12)

where \( \Phi \) is the cumulative normal distribution. The log-likelihood function used in estimation is straightforward and specified over these probabilities. The intuition of the probability relationship is clear. The latent variable is partitioned according to the six measured intervals recorded in the survey. The \( \mu \) are unknown parameters defining the cut points between the different probability categories (an ordering relationship, \( 0 < \mu_1 < \mu_2 < \ldots < \mu_5 \), is required to ensure positive probabilities). Estimates of the \( \mu \) are calculated from the estimated likelihood function for the Violations equation. The estimated coefficients vector \( \beta \) is itself of limited use in model evaluation. Rather, our interest is in estimating the marginal change in the probability for each of the six categories with respect to changes in the independent variables. Under the assumption of normality, the marginal values are calculated using the estimated \( \mu \) and \( \beta \) vectors and can be written as

\[
\begin{align*}
\frac{\partial \Pr (V = 1)}{\partial X} &= -\phi (\beta^T X) \beta, \\
\frac{\partial \Pr (V = 2)}{\partial X} &= (\phi (-\beta^T X) - \phi (\mu_1 - \beta^T X)) \beta, \\
\vdots & \\
\frac{\partial \Pr (V = 6)}{\partial X} &= \phi (\mu_5 - \beta^T X) \beta,
\end{align*}
\] (13)

where \( \phi \) is the normal density.

In the survey more than 60 structured questions were used to explore fishermen’s views and experiences of violation and enforcement. A procedure was therefore necessary in order to select variables for the Violations equation. Responses were grouped on theoretical grounds (for
example, questions relating to Social influence) and within each group questions were dropped at the outset if the variation in responses was very low (which was the case with a number of the Legitimacy questions), if it was apparent that the question had been misunderstood, or if there had been a significant number of non-responses. More formal pre-testing excluded potential variables exhibiting a high degree of colinearity with other candidate variables.

The variables included in the final Violations model are listed and described in Table 1. While it is apparent that the model excludes a number of interesting survey questions, for the reasons outlined above, we have at least one variable from each variable “group”. Note that all the non-continuous variables were coded such that, a priori, the expected sign on the coefficient in the model would be positive. An exception was the binary variable LEASE (see below) which was simply coded 1 for an affirmative response. Two variables measure financial Incentives: RESTR is an estimate of the extent to which a vessel’s quotas would restrict its potential gross earnings if they were fully complied with (on a percentage scale), while LEASE records whether or not the vessel leased in extra quota over and above its basic allowances. Deterrence is measured by SPROB, the fisherman’s subjective probability of detection if in violation of quota limits. SPROB is a scale variable with five ordered categories from 1 - “very high” - to 5 - “very low”. Social influence is measured by the variable PVIOLS which has five ordered categories from 1 - “all comply most of the time” - to 5 - “most regularly land over-quota fish”. The influence of a Moral or normative judgement is represented by the binary variable CONS which measures agreement or disagreement with the normative statement “quotas should be complied with because they are necessary to conserve fish stocks”. Three variables measure aspects of regulatory Legitimacy: FINSP, a 4-point scale recording the perceived fairness of the pattern of landings inspections (1 - “very fair” - to 4 - “very unfair”), PROS, the perceived prosecution rate

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11 A scaled regressor variable is an ordered categorical variable that is treated as a continuous variable in estimation. Testing of each scale variable was carried out to determine if a scale was appropriate in specifying the equation. In testing, dummy variables were defined for each level with a null hypothesis of no difference between levels.
for violations (1 - “always” - to 4 - “sometimes”) and PORULE, a binary variable measuring agreement or disagreement with the statement “quotas should be complied with because they are rules made by your PO”. Skipper and vessel characteristics were measured by two variables: the AGE of the skipper (a continuous variable) and the GROSS earnings of the vessel in the previous year (a twelve unit block continuous variable).

In order to address the endogeneity problem that might be introduced by including SPROB as a regressor in the Violations equation, we used a two-stage approach for testing a null hypothesis of no endogeneity in SPROB, following the procedure suggested by Rivers and Vong (1988). In the first stage, an auxiliary regression is modelled, where SPROB is specified as a function of exogenous deterrence variables that determine or influence the fishermen’s subjective probability of detection. Because SPROB is an ordered categorical variable, and given our assumption about the error distribution, an ordered probit maximum likelihood routine was used in estimation. From the fitted probability regression for SPROB the residuals are saved and included as a regressor to augment the Violations equation (note that the residual variable is in addition to the variables already specified in this equation). The null hypothesis of exogeneity then implies a test that the population parameter for the residual variable is zero (see Wooldridge 2002, p.474).

In addition to its role in testing for possible endogeneity, the Probability of Detection equation is of interest in its own right in that it measures exogenous factors that affect fishermen’s perceived probability of getting caught violating quotas. The equation was specified as

$$SPROB = f (CONVICT, BOARDS, INSPECS, EXPFISH) + v, \quad (14)$$

where $v$ is a measure of random influences and is assumed to be normally distributed. The four regressor variables are listed in Table 2. Two measure enforcement effort: BOARDS records the number of times the respondent’s vessel was boarded by fishery officers in the previous

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12 Substitution with mean values was used to remove the influence of the very small number of non-PO vessels in the sample.

13 see Wu (1973), Rivers and Vong (1988) and Davidson and MacKinnon (1993)
year; \textit{INSPECS} is the number of times the respondent’s landings were inspected in the previous year. Both variables are censored continuous variables measured from zero to four or more occurrences. \textit{CONVICT} records the number of times the skipper has been convicted of an offence related to landing over quota fish within the last ten years. This variable is also a censored continuous variable ranging from zero to three or more convictions. \textit{EXPFISH} is a continuous variable measuring the skipper’s fishing experience in years.

In estimating the \textit{Probability} equation, we were concerned with correctly accounting for the censored point in three of the four regressor variables. We tested for this by augmenting the equation with three dummy variables that defined the censored values. In all three cases, tests of significance of the dummy variables for the censored points were rejected and consequently they were dropped from the specification. In estimation of the \textit{Probability} equation, robust standard errors were allowed for using a Huber-White estimator of the variance-covariance matrix. The results are reported in Table 3. Note that because the estimated coefficients do not represent slope values it is difficult to interpret them directly. Nevertheless, both \textit{BOARDS} and \textit{INSPECS} are statistically unimportant and the latter appears to have an incorrect sign. On the other hand, \textit{CONVICT} has a small \( p \) value and the sign of the coefficient is intuitively correct, indicating that the greater the number of past convictions the greater the expectation of detection if in violation. Note that the cut points separating the probability distribution for the dependent variable are each statistically important.

The slope or marginal values for the \textit{SPROB} equation are reported in Table 4. The values shown for each regressor variable represent the marginal change in the probability of observing each indicated category of the dependent variable for a unit increase in the regressor variable, evaluated at its mean value. Thus, a unit increase from the mean in the number of convictions for quota offences increases the estimated probability that \textit{SPROB} = 1 or 2 ("very high" or
“reasonably high”) by $0.136 + 0.077 = 0.213$. Similarly, a unit increase in the number of convictions decreases the estimated probability that $SPROB = 5$ (“very low”) by 0.214. It is apparent that in the model most of the change in probability associated with this variable occurs in the tails of the distribution. None of the other variables were statistically significant.

In Table 5 we present the predicted probabilities for the categories of $SPROB$ for each category of $CONVICT$ from 1 (three or more convictions) to 4 (no convictions). It can be seen that in the absence of convictions there is a rather even spread of probabilities across all categories of $SPROB$, whereas the experience of conviction skews markedly the distribution of probabilities toward a perception of a “very high” risk of detection.

The test of the null hypothesis of no endogenous relationship between $SPROB$ and $VIOLS$, referred to above, gave a chi-squared statistic (1 degree of freedom) of 0.54 with a $p$ value of 0.462. Consequently, the null hypothesis of no endogeneity was not rejected by the data which allowed a single model estimation of the $Violations$ equation.

As for the $Probability$ equation, a maximum likelihood procedure was applied to the $Violations$ equation under the assumption that the latent variable follows a normal distribution. The ordered probit likelihood function employed was well behaved and convergence occurred within four to five iterations. Again, robust standard errors were allowed for using a Huber-White estimator of the variance-covariance matrix. The ordered probit estimates for the equation are reported in Table 6. The estimated model was robust with the null hypothesis of no regression equation easily rejected.\textsuperscript{14} Note, as before, that the cut points separating the probability distribution are statistically important. Table 7 reports the marginal effects calculated at mean values for all except the binary (dummy) variables ($LEASE$, $CONS$ and $PORULE$), for which the marginal effects refer to a change from 0 to 1. Recall that the dependent variable $VIOLS$

\textsuperscript{14} Further, throughout all the preliminary specifications and estimations of the model we observed no sign change for the important variables in the equation, i.e., those variables with $p$ values of less than 0.20.
is scaled from 1 (no over quota landings) to 6 (over quota by an estimated 30% or more).

From Tables 6 and 7 it is apparent that *PVIOLS, PROS, GROSS* and *AGE* are all statistically unimportant in the model, although the first two variables do at least have the expected signs (we had no prior expectations about the second two). *RESTR* and *PORULE* are both significant at $p \leq 0.05$ and have expected signs, indicating that higher levels of quota violations are associated with greater perceived restriction of earnings and, for PO members (the great majority of the sample), a disagreement with the view that PO rules should be complied with. The dummy variable *LEASE* is also significant at this level, although the positive sign on the coefficient suggests that fishermen leasing in extra quota are more likely to violate more, which was unexpected. The variables *CONS* and *FINSP* were both significant at $0.05 < p \leq 0.10$, so that lower levels of violations were associated with agreement that quotas are necessary for stock conservation and a judgement that the authorities were fair in the way they targeted vessel and landings inspections. Although having the expected sign, *SPROB* was only just significant at an acceptable level ($p = 0.15$).

Table 8 presents the predicted probabilities for the different categories of *VIOLS* for changes in the dummy variables *CONS, PORULE* and in the block continuous variable *RESTR* as its value goes from 1 (quotas not perceived to restrict earnings) to 6 (potential earnings restricted by quotas by more than 30%). The table also gives the predicted probabilities for the base model, from which we can see that nearly 41% of fishermen are predicted to violate their quota limits by around 10% ($VIOLS = 3$) and approximately 18% of fishermen are predicted to violate their quotas by more than this ($VIOLS = 4-6$). From the predicted probabilities for *RESTR*, it can be seen that if *RESTR = 1*, some 98% of the distribution is defined over the first three *VIOLS* categories indicating quota violations of around 10% or less, while if *RESTR = 6* the probability distribution has shifted to where 92% of the distribution is in categories of 20% violations or
greater. If \( CONS = 0 \), which represents agreement that quotas are necessary to conserve stocks, the probability distribution is shifted toward lower categories of \( VIOLS \). A similar pattern is evident for \( PORULE = 0 \), representing agreement that quotas should be adhered to because they are rules made by the fisherman’s PO.

4 DISCUSSION AND CONCLUSIONS

In this study we specifically tested for, but found no statistical evidence of, endogeneity between the variable representing the respondents’ own estimation of violation levels and the variable representing the own estimation of the probability of detection if in violation. This result enabled us to estimate a single equation model of quota violations. The finding of no endogenous relationship between the subjective probability of detection and the violation level may be related to the fact that in our survey we necessarily framed our questions about violation in the recent past whereas the perceived risk of detection is formed contemporaneously. We need to assume that the perceived risk has not changed significantly in the interim for exogenous reasons, and indeed we are not aware of any reason why this should be the case.

The procedure used to test for endogeneity required the estimation of an “auxiliary” equation to explain the perceived risk of detection. Interestingly, this equation showed that fishermen in our sample appeared not to form their subjective risk of getting caught on the basis of their past experience of either landings inspections in port or logbook inspections at sea, suggesting that, as things stand, the frequency of inspections \( \text{per se} \) has little deterrent effect, perhaps because violators are skilled at concealing over-quota fish from inspectors, or because the standard of inspections is simply inadequate. There was, however, a strong association between the subjective risk of detection and past experience of successful convictions. The conclusion is that, currently in this fishery, securing conviction and sanction is in practice the most significant
deterrent available to the authorities and that the quality (thoroughness) as well as quantity (frequency) of inspections may need to be improved.

Levels of quota violations in the fishery appeared to be driven mainly by financial incentives and disincentives. Higher violations were positively associated with perceptions of greater constraints on earnings and, although only weakly, negatively associated with the perceived risk of getting caught. Interestingly, leasing in of additional quota allowances was associated with violation rather than compliance. This result was somewhat surprising, since we would expect the ability to lease extra quota to mitigate incentives to exceed quotas illegally, and hence expect to observe an inverse relationship between leasing and violation. It may be that cheating and leasing appear as “behavioural complements” rather than substitutes because some violators do offset their violation levels by leasing extra quota, whereas some compliers have no financial need to do either. The finding may also reflect efforts by POs to require known violators to account for suspected quota excesses after the event by arranging quota leases.

No social influence appeared to be significant in the determination of violation levels, although the variable included in the model (the perceived behaviour of peers) did have the expected sign. There was some evidence of a normative (moral) influence on violations, with the recognition of the conservation value of quotas being more associated with lower levels of violation, although it is possible that violators may be more likely to justify their actions by negating the utility of quota controls in an interview. The absence of a range of factors related to the legitimacy of management is mainly attributable to overwhelmingly negative views about many aspects of the management system, particularly regarding the role of the EU and the use of quotas in management. Nevertheless, we found a significant association between recognition of the authority of the POs in implementing quotas and lower levels of violation. The finding that favourable judgements about the fairness of inspection patterns were positively associated with
lower levels of violation was taken as an expression of the legitimacy of the enforcement system (in terms of procedural fairness) but could, on the other hand, be evidence of a targeting of inspections against likely offenders.

An earlier study of the same fishery (Hatcher et al. 2000) employed a binary probability model to estimate the Violations equation. The ordered response models used in the present study are, we believe, more effective in using the information contained in the survey data, enabling an explicit examination of the predicted probabilities for a range of values of the dependent variable associated with different categories of the regressor variables. In this study we also attempted to measure more or less directly the financial incentive to violate quotas, and this appeared to be the most significant factor in the Violations model. The finding of the previous study that a feeling of involvement in the design and operation of the management system was associated with greater compliance could not be replicated here. Variables related to involvement or participation all had near-zero coefficients and negative signs in early specifications of the model. Notwithstanding this, the present study does provide some support for the importance of local structures in fisheries management with the finding that an index of support for PO rules was associated with lower violation levels.
References


<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>Definition</th>
<th>Measured value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
<td>VIOLS</td>
<td>landings over-quota (%)</td>
<td>ordered categorical</td>
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<tr>
<td>Incentives</td>
<td>RESTR</td>
<td>restriction of earnings due to quotas (%)</td>
<td>block continuous</td>
</tr>
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<td>LEASE</td>
<td>leasing in extra quota</td>
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<tr>
<td>Deterrence</td>
<td>SPROB</td>
<td>subjective probability of detection</td>
<td>scale variable</td>
</tr>
<tr>
<td>Moral</td>
<td>CONS</td>
<td>obligation to comply for stock conservation</td>
<td>binary</td>
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<tr>
<td>Social</td>
<td>PVIOLS</td>
<td>perceived violation behaviour of peers</td>
<td>scale variable</td>
</tr>
<tr>
<td>Legitimacy</td>
<td>FINSP</td>
<td>fairness of inspection patterns</td>
<td>scale variable</td>
</tr>
<tr>
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<td>PROS</td>
<td>prosecution rate for offenders</td>
<td>scale variable</td>
</tr>
<tr>
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<td>PORULE</td>
<td>obligation to obey PO rules</td>
<td>binary</td>
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<tr>
<td>Characteristics</td>
<td>GROSS</td>
<td>vessel gross earnings</td>
<td>block continuous</td>
</tr>
<tr>
<td></td>
<td>AGE</td>
<td>skipper age</td>
<td>continuous</td>
</tr>
</tbody>
</table>

Table 1. Variables in the *Violations* model
<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>Definition</th>
<th>Measured value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
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<td>subjective probability of detection</td>
<td>scale variable</td>
</tr>
<tr>
<td>Deterrence</td>
<td>CONVICT</td>
<td>convictions over ten years</td>
<td>censored continuous</td>
</tr>
<tr>
<td></td>
<td>BOARDS</td>
<td>vessel boardings in previous year</td>
<td>censored continuous</td>
</tr>
<tr>
<td></td>
<td>INSPECS</td>
<td>landings inspections in previous year</td>
<td>censored continuous</td>
</tr>
<tr>
<td>Characteristics</td>
<td>EXPFISH</td>
<td>skipper experience</td>
<td>continuous</td>
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Table 2. Variables in the *Probability of Detection* model
<table>
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<th>Variable</th>
<th>Coefficient</th>
<th>p value</th>
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<tr>
<td>CONVICT</td>
<td>0.590</td>
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<td>BOARDS</td>
<td>0.166</td>
<td>0.303</td>
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<td>INSPECS</td>
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<td>0.929</td>
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<td>EXPFISH</td>
<td>-0.008</td>
<td>0.616</td>
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</table>

<table>
<thead>
<tr>
<th>Cut points</th>
<th>Coefficient</th>
<th>Standard error</th>
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<td>$\mu_1$</td>
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<td>2.614</td>
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</tr>
<tr>
<td>$\mu_4$</td>
<td>3.217</td>
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n = 70; log-likelihood = -100.28; Wald chi-squared = 15.85 ($p = 0.003$)

Table 3. Ordered probit Probability of Detection model
<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>SPROB</td>
<td></td>
<td><strong>0.136</strong></td>
<td><strong>0.077</strong></td>
<td>0.022</td>
<td>-0.021</td>
<td>-0.214**</td>
</tr>
<tr>
<td>CONVICT</td>
<td></td>
<td>0.038</td>
<td>0.022</td>
<td>0.006</td>
<td>-0.006</td>
<td>-0.060</td>
</tr>
<tr>
<td>BOARDS</td>
<td></td>
<td>0.003</td>
<td>-0.002</td>
<td>-0.001</td>
<td>0.000</td>
<td>0.005</td>
</tr>
<tr>
<td>INSPECS</td>
<td></td>
<td>0.002</td>
<td>-0.001</td>
<td>0.000</td>
<td>0.000</td>
<td>0.003</td>
</tr>
<tr>
<td>EXPFISH</td>
<td></td>
<td>+ significant at p = 0.20; * significant at p = 0.10; ** significant at p = 0.05</td>
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Table 4. Marginal effects (at mean values) in the *Probability of Detection* model
<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
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<tr>
<td>SPROB</td>
<td>1</td>
</tr>
<tr>
<td>CONVICT</td>
<td>0.844</td>
</tr>
<tr>
<td></td>
<td>0.662</td>
</tr>
<tr>
<td></td>
<td>0.432</td>
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<tr>
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<td>0.223</td>
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Table 5. Predicted probabilities for CONVICT in the Probability of Detection model
<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>p value</th>
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<tbody>
<tr>
<td>RESTR</td>
<td>0.469</td>
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<tr>
<td>LEASE</td>
<td>0.719</td>
<td>0.036</td>
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<tr>
<td>SPROB</td>
<td>0.151</td>
<td>0.153</td>
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<tr>
<td>CONS</td>
<td>0.833</td>
<td>0.063</td>
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<tr>
<td>PVIOLS</td>
<td>0.161</td>
<td>0.241</td>
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<tr>
<td>FINSP</td>
<td>0.292</td>
<td>0.095</td>
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<tr>
<td>PROS</td>
<td>0.109</td>
<td>0.422</td>
</tr>
<tr>
<td>PORULE</td>
<td>0.745</td>
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</tr>
<tr>
<td>GROSS</td>
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<td>0.447</td>
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<td>AGE</td>
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<td>0.289</td>
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</table>

<table>
<thead>
<tr>
<th>Cut points</th>
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<th>Standard error</th>
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<tr>
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<td>4.333</td>
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<td>$\mu_2$</td>
<td>5.298</td>
<td>1.102</td>
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<td>$\mu_3$</td>
<td>6.427</td>
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<td>$\mu_4$</td>
<td>7.401</td>
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<tr>
<td>$\mu_5$</td>
<td>8.050</td>
<td>1.200</td>
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n = 70; log-likelihood = -89.44; Wald chi-squared = 45.22 ($p = 0.000$)

Table 6. Ordered probit Violations model
<table>
<thead>
<tr>
<th>Variable</th>
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<tbody>
<tr>
<td>VIOLS</td>
<td>1 2 3 4 5 6</td>
</tr>
<tr>
<td>RESTR**</td>
<td>-0.090** -0.092** 0.055** 0.093** 0.026* 0.008+</td>
</tr>
<tr>
<td>LEASE**</td>
<td>-0.155* -0.123** 0.100+ 0.132** 0.034+ 0.011+</td>
</tr>
<tr>
<td>SPROB+</td>
<td>-0.029+ -0.029+ 0.018 0.030+ 0.008 0.003</td>
</tr>
<tr>
<td>CONS*</td>
<td>-0.212+ -0.111** 0.150+ 0.135** 0.030* 0.009+</td>
</tr>
<tr>
<td>PVIOLS</td>
<td>-0.031 -0.031 0.019 0.032 0.009 0.003</td>
</tr>
<tr>
<td>FINSP*</td>
<td>-0.056+ -0.057* 0.035 0.058* 0.015 0.005</td>
</tr>
<tr>
<td>PROS</td>
<td>-0.021 -0.021 0.013 0.021 0.006 0.002</td>
</tr>
<tr>
<td>PORULE**</td>
<td>-0.122** -0.149** 0.049 0.152* 0.051 0.020</td>
</tr>
<tr>
<td>GROSS</td>
<td>-0.007 -0.008 0.005 0.008 0.002 0.001</td>
</tr>
<tr>
<td>AGE</td>
<td>-0.003 -0.003 0.002 0.003 0.001 0.000</td>
</tr>
</tbody>
</table>

*significant at $p = 0.20$; ** significant at $p = 0.10$; *** significant at $p = 0.05$

Table 7. Marginal effects (at mean values) in the Violations model
<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>VIOLS</td>
<td>base model</td>
<td>0.114</td>
<td>0.291</td>
<td>0.408</td>
<td>0.156</td>
<td>0.025</td>
<td>0.006</td>
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<tr>
<td></td>
<td>RESTR = 1</td>
<td>0.492</td>
<td>0.336</td>
<td>0.153</td>
<td>0.018</td>
<td>0.001</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>RESTR = 6</td>
<td>0.009</td>
<td>0.072</td>
<td>0.312</td>
<td>0.366</td>
<td>0.153</td>
<td>0.089</td>
</tr>
<tr>
<td></td>
<td>difference</td>
<td>0.483</td>
<td>0.265</td>
<td>-0.159</td>
<td>-0.348</td>
<td>-0.152</td>
<td>-0.088</td>
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<tr>
<td>CONS</td>
<td>CONS = 0</td>
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<td>0.371</td>
<td>0.272</td>
<td>0.053</td>
<td>0.005</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>CONS = 1</td>
<td>0.087</td>
<td>0.260</td>
<td>0.422</td>
<td>0.188</td>
<td>0.035</td>
<td>0.009</td>
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<tr>
<td></td>
<td>difference</td>
<td>0.212</td>
<td>0.111</td>
<td>-0.150</td>
<td>-0.135</td>
<td>-0.030</td>
<td>-0.008</td>
</tr>
<tr>
<td>PORULE</td>
<td>PORULE = 0</td>
<td>0.165</td>
<td>0.332</td>
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<td>0.113</td>
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<td>0.003</td>
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<tr>
<td></td>
<td>PORULE = 1</td>
<td>0.043</td>
<td>0.183</td>
<td>0.421</td>
<td>0.265</td>
<td>0.066</td>
<td>0.023</td>
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<tr>
<td></td>
<td>difference</td>
<td>0.122</td>
<td>0.149</td>
<td>-0.049</td>
<td>-0.152</td>
<td>-0.051</td>
<td>-0.020</td>
</tr>
</tbody>
</table>

Table 8. Predicted probabilities for RESTR, CONS and PORULE in the Violations model