INDIVIDUAL DISCOUNT RATE AND REGULATORY COMPLIANCE IN A DEVELOPING COUNTRY FISHERY

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ABSTRACT

Studies on compliance with fishing regulations have looked at fishery crimes for which the offender faces a one-period decision problem of maximizing an expected utility. Moreover, the returns to the crimes are uncertain because the offender may lose them if caught. This paper extends these models by considering a fishery crime that generates flow of returns until the offender is caught and then punished. Consequently we incorporate into the existing model, the influence of dynamic deterrence in which the discount rate affects violation levels. The predictions of the model are tested on data from an artisanal fishery in Ghana.

Keywords: Fishery; Regulation; Compliance; Dynamic Model

INTRODUCTION

In spite of the overwhelming evidence that world fisheries are in crisis, with fishing effort far exceeding sustainable levels, all forms of fishing regulations are constantly being violated worldwide. Moreover, some fisheries have completely collapsed or are much depleted, which poses a serious threat to food security and sustainable livelihood, especially in developing coastal countries (Pauly and Zeller, 2003). To reverse or halt the overfishing problem, adequate levels of compliance must be enforced. A possible means of achieving this is to investigate reasons for non-compliance and then formulate policies accordingly. In view of this, following the theoretical model of Becker (1968), and later developed by Ehrlich (1973) and Block and Heneike (1975), a number of empirical research have been done to verify the determinants of non-compliance with fishery regulations. Some of the leading works in this area are Furlong (1991), Kuperan and Sutinen (1994), and Hatcher et al. (2000). The theoretical basis of these models sees the fisher as a self-interested and rational economic agent who aims at maximizing expected utility from illegal fishing. Consequently, he engages in illegal fishing if the expected gain from violation outweighs the gain from legal fishing.

The crime models applied to violation of fishery regulations such as closed area, quantity restriction, or gear restriction, have considered a situation where the potential violator faces a one-period decision problem of maximizing an expected utility (see Sutinen and Anderson, 1985; Anderson and Lee, 1986; Sutinen and Hannessey, 1986; Furlong, 1991; Kuperan and Sutinen, 1994; Charles et al., 1999; Sutinen and Kuperan, 1999; Hatcher et al., 2000; Eggert and Lokina, 2005; Hatcher, 2005; and Chavez and Salgado, 2005 for examples). Following the portfolio model of time allocation of Heineke (1978), time is included in the models and treated as a one-period decision variable (e.g. see Furlong, 1991). Thus the fisher is assumed to have a fixed amount of time from which he spends a positive amount on illegal fishing (See Furlong, 1991; Sutinen and Kuperan, 1999). Alternatively, the fisher faces a one-period binary decision problem of obeying a specific regulation, say catch quota, or not (See e.g. Hatcher et al., 2000). However, for crimes that are committed repeatedly, such as the acquisition and use of nets with illegal mesh size that is considered in this paper, the uncertainty of time of detection makes it difficult, if not impossible, for the potential violator to aggregate the uncertain gains from the crime to be used for the one-period or static decision-making. Furthermore, the fact that it is possible for a violator to get away with the crime for some time implies that he will be interested in the survival of the criminal activity, which will depend on the probability that he will be caught, given that he managed to get away with the crime in the past (i.e. instantaneous conditional probability) (Leung, 1991). Thus, the offender will be confronted with the task of choosing an optimal path of violation. Since the expected returns are obtained over a period of time, in addition to instantaneous conditional probability of detection and arrest, and the expected fine, the optimal path will depend on the individual discount rate. This type of crime is, therefore, modeled as a dynamic deterrence problem (see for example Davis, 1988; Nash, 1991; Leung, 1991, 1994).

In this paper, we extend the existing work on regulatory compliance in a fishery to investigate whether individual discount rate, among other possible factors, influence the intensity of violation of mesh size regulation, which is committed repeatedly. The predictions of the model are tested with data from an artisanal fishery in Ghana. The artisanal or inshore fishery in Ghana is characterized by the use of destructive fishing gears (Atta-Mills et al., 2004), including nets with patches of nets with small mesh sizes that target juvenile stock, leading to overfishing. This is a typical fishery crime that constitutes an example of a dynamic deterrence problem and is therefore modeled as such in this paper. Results of this study indicate that the individual discount rate is statistically significant and positively related to intensity of violation of the mesh size regulation. Furthermore, risk and severity of punishment, social pressure, age of the skipper, as well as legitimacy, fairness and feasibility of the mesh size regulation considered in earlier studies on regulatory compliance in fisheries (see e.g. Hatcher et al., 2000) are also statistically significant. Moreover, skippers who were aware that their intensive fishing activities were responsible for the declining fishery stock had, on the average, higher intensity of violation.

The rest of the paper is organized as follows: we present the basic model in section 2 followed by the survey design and data description in section 3. In section 4, we present and discuss the estimation of our model and the final section, i.e. section 5, has the conclusion of the paper.

THE THEORETICAL FRAMEWORK

The model for this study is a dynamic deterrence model that closely follows the logic of Davis (1988), Nash (1991) and Leung (1991, 1994) and is carefully tailored to suit the problem of violating the regulation on the use of illegal mesh sizes. Ideally, a composite index of the illegal mesh size, the size of the illegal net, and the frequency of use of the illegal net should measure the intensity of violation of the mesh size regulation. However, if constant returns to scale are assumed between this index and effort in the fishery, then the level and composition of harvest, for any given level of stock, may be a good proxy for the intensity of violation of the mesh regulation (e.g. see Turvey, 1964; and Boyd, 1966 for similar assumption of the relationship between fishing capacity and effort). Note that, notwithstanding the weakness associated with the use of harvest as a proxy, data on size and intensity of use of illegal nets are much more difficult to obtain than fish caught by illegal nets, which is normally traded in a market and consequently not very easy to conceal. Moreover, like other empirical studies on violation of fishing regulations, we rely on self-reported data, all of which may suffer from some degree of falsification.

Consider a standard Schaefer model in which the level of harvest perfectly correlates with the level of effort for any given level of stock. Suppose that a potential violator i of the mesh size regulation has a profit function given by $\pi^i(y_i, x_i, k_i)$, where y_i is the harvest of juvenile stock, x_i is harvest of mature stock and k_i, following Boyce (1996), is a *common* fixed cost of harvest, which is independent of the composition of catch. The nets with legally accepted mesh can only harvest the mature stock but those with the illegal mesh can harvest both the mature and the immature or juvenile stock. Let *illegal net* denote fishing net that has a patch of the authorized mesh size (i.e. *legal net*) and a patch of unauthorized or small mesh size. If the offender uses an illegal net, he targets both mature and juvenile stock (i.e. $x > 0$ and $y > 0$) and makes a profit of $z^i(x_i) + d^i(y_i) - k_i$, where $z^i(x_i)$ and $d^i(y_i)$ are individual specific gross revenue (i.e. variable profit) functions for x_i and y_i respectively. On the other hand, if he uses the legal net he targets only the mature stock (i.e. $x > 0$ and $y = 0$), and his profit is $z^i(x_i) - k_i$. This specification, which assumes that harvest is linear and separable in the use of the smaller and the approved mesh sizes, is consistent with Charles et al. (1999). We refer to the catch with an illegal net as illegal harvest and that of the legal net as legal harvest. Thus, the profit function of i is

$$\pi^i(y_i, x_i, k_i) = \begin{cases} z^i(x_i) + d^i(y_i) - k_i & y > 0 \\ z^i(x_i) - k_i & y = 0 \end{cases}, \tag{1}$$

where $d_y^i > 0, d_{yy}^i \le 0$, $z_x^i > 0$, and $z_{xx}^i \le 0$. Furthermore, if i is caught, he pays a fine F_i, which includes a fixed amount $\overline{f}$ and an individual specific cost of the net with the small mesh size $\tilde{f}_i$, with a probability q of being fined given that he is arrested. Since we have assumed that the size of the net correlates with harvest, it follows that $\tilde{f}_i(y_i)$ and $\tilde{f}_y > 0$. Following the dynamic deterrence model of Davis (1988), we assume that each violator does not know the exact time of detection but only some probability distribution of the time of detection, denoted $g(t) \equiv \frac{\partial G(t)}{\partial t}$, where the probability that detection would have occurred at time t in the future is the cumulative density function (cdf), $G(t)$. The expected present value of the fine is therefore

$$q_i \int_0^\infty F_i g_i(t) e^{-\delta} dt . \tag{2}$$

We assume an infinite planning horizon because fishing gears are usually bequeathed to subsequent generations. Although violators do generally recidivate, artisanal fishers are known to live in abject poverty and a generic violator of the mesh size regulation is not likely to repeat the offence if the patches of the net with small mesh size are seized. Indeed Smith and Gartin (1989) noted that harsher punishment reduces the propensity to recidivate. Following the literature on dynamic deterrence (see e.g. Davis, 1988; Nash, 1991; and Leung, 1991, 1994), by assuming an infinite planning horizon, our model becomes an illegal-legal two-segment dynamic problem. The value function is a discounted stream of profit given by

$$V^i(y) = \int_0^\infty e^{-\delta_i t} \left\{ \left(z^i(x_i) + d^i(y_i) - k_i \right)\left(1 - G_i(t)\right) + \left(z^i(x_i) - k_i \right) G_i(t) - q_i F_i g_i(t) \right\} dt , \tag{3}$$

where $V^i(.)$ is the value-function and δ_i is the individual benefit discount rate. It is assumed that the discount rate is positive, since the violator will prefer a given sum of money today to having the same amount in the future. Until detection, the offender will maximize profit from the illegal harvest. But after he is arrested, the patch with the illegal mesh will be seized and he will maximize profit from legal harvest. To establish a relationship between the intensity of violation and the timing of detection, let the probability that the offence will be detected within a very small interval of time t given that it had not been detected in the past (i.e. the hazard rate or the instantaneous conditional probability) be the conditional density

$$p\left(y_i, \varsigma\right) = \frac{g(t)}{1 - G(t)} , \tag{4}$$

where the probability that the act would have survived up to time t (i.e. survivor function) is $(1 - G(t))$ and ς is constant enforcement effort which is henceforth normalized to one. From equation 4, $-\frac{d \ln(1 - G(t))}{dt} = p(y_i)$, which implies that $(1 - G(t)) = e^{-\int_0^t p(y_i) d\tau}$.

The fishery under consideration is characterized by uncertain seasonal upwelling that produces planktons for the fish stock and is also organized as a *regulated* open access, where fishers can harvest any quantity with the authorized mesh size. This makes it difficult for artisanal fishers to predict the trend of catch. We therefore assume that the fisher's best forecast of future catches is the present catch. Consequently, if we assume that the periodic harvest in this model is time independent or constant over time[i], then $(1 - G(t)) = e^{-p(y_i)t}$, $G(t) = 1 - e^{-p(y_i)t}$ and

$g(t)=p(y_i)e^{-p(y_i)t}$. If the expression for $g(t)$ (i.e. $g(t)=p(y_i)e^{-p(y_i)t}$) is substituted into the objective function and all other values are assumed to be constant over time, we have equation (5). Moreover, since the objective of the offender is to maximize benefit from the illegal activity, y_i is the explicit choice variable in the optimization program

$$V^i\left(y\right)=\frac{d^i\left(y_i\right)-p\left(y_i\right)q_iF_i}{\delta_i+p\left(y_i\right)}+\frac{z^i(x_i)-k_i}{\delta_i}. \qquad (5)$$

The first term on the right hand side of equation (5) is the infinite discounted expected return from engaging in the rule violation, with the discount factor adjusted by the hazard rate, and the second term is the infinite discounted stream of profit from harvesting legally. If the expected return is not positive, the fisher will not violate the regulation. Thus, the magnitude of the expected return provides the incentive for the profit-maximizing agents to violate the regulation (Chang and Ehrlich, 1985). Since the second term of equation (5) does not have the decision variable, the offender's decision problem is the first term. That is[ii]

$$V^{i1}\left(y\right)=\frac{d^i\left(y_i\right)-p\left(y_i\right)q_iF_i}{\delta_i+p\left(y_i\right)}\ . \qquad (6)$$

It is straightforward to see that, from equation (6), the elasticity (i.e. $\eta_s=-\partial\ln(V^{i1})/\partial\ln s$, where $s=F,p$) with respect to fine is less than the elasticity with respect to instantaneous conditional probability. This implies that the value function will be more sensitive to an increase in the conditional probability of detection than an equal percentage increase in fine. Thus, an increase in the probability of detection, say through increased enforcement effort, is more likely to prevent violation than an equal percentage increase in fine. On the other hand, in a static setting, a given percentage increase in probability of detection could be compensated by an equal percentage reduction in fine to keep the value function constant. This presents a clear distinction between modeling a repeating crime as a dynamic or a static problem. Furthermore, by modeling the problem as a dynamic one, an additional variable (i.e. discount rate) has been identified. It is noteworthy that if risk neutrality is assumed, then equation 6 is also an indirect utility function.

From equation (6), if an interior solution exists, the offender's decision problem becomes

$$y_i^*=\arg\max\left(\frac{d^i(y)-p\left(y_i\right)qF_i}{\delta_i+p\left(y_i\right)}\right)\ . \qquad (7)$$

From equation (7), the general form of the supply of violation function is specified as

$$y_i^*=y_i^*\left(p,\delta_i,qF_i,\mathrm{B}_i\right). \qquad (8)$$

Following Furlong (1991) and Hatcher et al. (2000), B_i, which is a utility shift vector across fishers, includes psychological and socioeconomic characteristics of the skipper such as age and wealth of the fisher, perception of social pressure, legitimacy of the regulation, fairness of the regulation, feasibility of rule, and the fisher's perception of the level of the fish stock compared to the past. The psychological and social variables are included because, although courts of law impose very low fines that do not fit fishery crimes, a good number of fishers comply with regulations even if it is financially beneficial to violate them (Kuperan and Sutinen, 1994; and Sutinen and Kuperan, 1999). Consequently, current developments in both the theoretical and empirical literature have recognized this shortfall and as a result, have controlled for these factors in crime models applied to fisheries (e.g. see Hatcher et al., 2000).

SURVEY DESIGN AND DATA DESCRIPTION

The data for the analysis were collected by a survey of fishermen from Komenda-Edina-Eguafo-Abrew (KEEA) District, which is a district of Ghana where fishing activities are intense. Since some types of nets are known to have different patches with varying mesh sizes, including the illegal types (i.e. nets with meshes that are less than 25mm in stretched diagonal length), our population included all skippers who use these nets within the district. From the population, a random sample of 310 skippers constituting approximately 41% were interviewed between June and July 2005.

The fishery sector in Ghana has undergone considerable changes with regard to improvement in artisanal fishing gears, which has led to overexploitation of the fishery stock[iii]. Since the beginning of the 20th century, outboard motors were introduced, fish processing and storage facilities improved, and fishing nets and netting materials also improved, resulting in increased catch (Koranteng, 1992). The beach seine net was the first to be introduced, and soon after an encircling net was introduced and later developed into a purse seine net locally called *watsa* net with mesh size of about 50-60 mm. This was further improved to have thinner twine and contain much smaller mesh sizes of 10-13 mm called *poli*. Fishery scientists consider this net very destructive to the fish stock since it is capable of harvesting large shoals of juvenile fishes. The most recent and popular gear is *ali-watsa* net, which is a combination of a destructive drifting gillnet with mostly small mesh sizes known as *ali*, and *watsa* nets (Koranteng, 1992; Walker, 2002). Furthermore, some fishermen within the Central Region of Ghana have adapted the *Ali* net into a type of purse net called *Sarti.* These nets are used along the entire coastal zone of Ghana.

By 1984, the practice had become pervasive posing a serious threat to the resource sustainability. Consequently, the government through the Fisheries Department enacted a law banning the use of mesh sizes smaller than 25mm in stretched diagonal length. Bodies charged with the responsibility of enforcing this law are the Ghana Navy, Department of Fisheries and the Judiciary. However, due to limited budget of government, monitoring and enforcement are far from perfect along the entire coastline.

Before the questionnaires were administered to the skippers, an approval was sought from the chief fisherman of the district, who is highly respected by all the fishermen[iv]. A questionnaire was administered to each of the skippers in a face-to-face interview. The interviewers informed the respondents of their mission and assured them that they were not collecting the information for the fishery department or the state and also that their responses will be treated with strict confidentiality. To guarantee that the responses were not contaminated by opinions of others, it was ensured that a respondent was interviewed alone. Furthermore each respondent was given a participation fee of \$2.24US, which is equivalent to what previous researchers who visited the community paid each skipper who participated in a similar interview for his time. The questionnaire included questions on demographic characteristics; wealth of the skipper; fishing nets and other fishing activities of the fishing unit; skipper's perception of the mesh size regulation and violation rate; subjective instantaneous conditional probabilities of detection, arrest given detection, and fine given arrest; and the skipper's confidence in the chief fisherman and district fisheries officers in regulating fishing activities.

The questions relating to fishing activities include the type of net, mesh size compositions of the net, value of catches of juvenile fishes that could not have been caught if the illegal mesh were not used, and the value of big fishes in the catch attributable to mesh sizes of an inch or above during the last one week of fishing. Since the chief fisherman in whom the fishers have a great deal of confidence approved the survey, the respondents willingly participated[v]. Only 3 (0.010%) respondents refused to give information on mesh sizes of their nets, 6 (0.019%) do not use illegal mesh size but all the rest (i.e. 301) indicated that they fish with it. The mean value of the catch of juvenile fishes[vi] was \$146US and the fine for violation (i.e. f_i), as noted earlier, is the sum of the fixed fine (i.e. $\overline{f}$) of \$112US and the replacement cost of the illegal nets (i.e. $\tilde{f}_i$). The mean expected fine was \$241US.

To communicate the question on perception of instantaneous conditional probabilities to the respondents in a simple way, a 5-point scale ranging from *very high* (50% or more) to *very low* (1% or less) in Hatcher et al. (2000) was used[vii]. Only 14% indicated that the subjective probability of detection is 50% or more, while the corresponding figure for the probability of 1% or less was about 20%. On the other hand, 33% indicated that the probability of arrest given detection is 50% or more, and only 6% indicated that the probability of being fined given arrest is 50% or more.

The question of the skipper's perception of violation rate required answers on a continuous scale. Sixty-five percent indicated that at least 80% of all the fishers within the district violate the regulation. Furthermore, only half of the skippers who agreed that there is a general decline in the stock within the management area indicated that the main cause of the decline is overfishing. Moreover, regarding the questions on fishers' perception of the fishing regulation, which included whether the government is doing the right thing by imposing the regulation and whether the regulation will improve the well-being of the fishers as a group, only about 11% of the skippers agreed. As high as 70% agreed that the mesh regulation is unfair to fishers. The responses were measured on a five-point Likert-scale ranging from *strongly agree* to *strongly disagree*.

To determine the individual rate of time preference, we employed the choice design of Cropper et al. (1992), and Poulos and Whittington (2000). The respondents were asked to choose one out of two hypothetical fishery projects. Project ***A*** could increase the skipper's income once by an amount at the end of the month in which the data was collected, and Project ***B*** could increase it once by twice the amount in six months' time. After the choice was made, the respondent is asked to indicate the value for project ***B*** that would make him indifferent between the two projects. We used this matching, and following Pender (1996) and Holden et al. (1998), the instantaneous individual discount rate was computed as $\delta = \log\left(\alpha_2/\alpha_1\right)$, where α_2 is the amount quoted by the skipper, and α_1 is the amount project **A** will offer. About 39% of the skippers had less than 100% discount rate and the mean was 131%[viii]. From personal interviews with the fishers, usurious moneylenders charge compounding monthly interest rate of between 20% and 30% on loans to fishers, who usually live in abject poverty and do not have collaterals to secure loans from formal financial institutions. Consequently, the high figures for the discount rate are not unexpected[ix].

ESTIMATION OF INTENSITY OF VIOLATION FUNCTION

Since most of the variables could not be measured directly, proxies were used. First, the dependent variable, intensity of violation, is calculated as the value of juvenile fishes in an illegal catch per day, averaged over the last one week's catch[x]. Secondly, following Furlong (1991), the instantaneous conditional probability was considered as a vector of the instantaneous conditional probabilities of detection and of arrest given detection.

Table 1: Ghana-Summary Statistics and Definition of Variables for Regression Analysis of Intensity of Violation of Mesh Size Regulation

Variable Description	**Mean**	**Std. Dev.**
Intensity of Violation per Boat (Value of Illegal Catch in USD)	143.12	424.88
Instantaneous Conditional *Probability of Detection* (=1 if reported value is at least 0.1; 0 otherwise)	0.61	0.49
Instantaneous Conditional *Probability of Arrest Given Detection* (=1 if reported value is at least 0.1; 0 otherwise)	0.64	0.48
Expected Total Fine (in USD)	241.28	1155.09
Individual Discount Rate (Continues)	1.31	0.71
Age of Skipper (Continues)	40.68	11.43
Social Pressure (i.e. perception of % violators)	0.71	0.23
Wealth of Skipper (in USD)	316.88	487.12
Dummy for Ownership (=1 if skipper owned; 0 otherwise)	0.47	0.50
Dummy for Exogenous Factors Leading to Declining Stock (=1 if perceived to be exogenous; 0 otherwise)	0.49	0.50
Dummy for Regulation *Protects Well-being* (1-5:strongly disagree-strongly agree)	1.81	1.08
Dummy for Regulation *Protects Stock* (1-5:strongly disagree-strongly agree)	1.65	1.06
Dummy for Regulation is *Fair* (1-5:strongly disagree-strongly agree)	2.35	1.17
Dummy for Regulation is a *Right Thing* (1-5:strongly disagree-strongly agree)	1.76	1.02

Source: The data is from survey conducted by the author in 2005.

For the purpose of estimation, the 5-point scale for the probabilities was categorized in a binary form, such that the probability values of at least 0.1 were considered as 1 and values of at most 0.05 were assigned zeros following Furlong (1991), and Hatcher et al (2000). The two probabilities were weakly correlated, with a correlation coefficient of 0.08, and hence did not pose any multicollinearity problem in the regression.

Thirdly, the fine was calculated as follows. The fixed fine was added to the replacement cost of the illegal net and then the result was multiplied by the probability of being fined, given an arrest.

Furthermore, the perceived proportion of fishers who violate the regulation was used as an indicator for social pressure. The proxy for legitimacy of rule is the statement that *government is doing the right thing by imposing the regulation,* and feasibility of the regulation, from the point of view of the fishers, are denoted by the statements that the *regulation will improve the well-being of fishers as a group,* and *the regulation will protect the fish stock*. The definition of the variables used for the analysis and their summary statistics are provided in Table 1.

It is noteworthy that, as a typical feature of data on many socioeconomic characteristics, our data on age of the skipper and wealth were positively skewed. Following Mukherjee (2003), the variables were logged to transform them towards normality before they were used in the regression.

Table 2: Ghana-Ordinary Least Square Regression Results for Determinants of Intensity of Violation of Mesh Size Regulation

	(1)	**(2)**
Instantaneous Conditional Probability of Detection	-0.227	-0.230
	(0.059)***	(0.058)***
Instantaneous Conditional Probability of Arrest given Detection	-0.193	-0.201
	(0.056)***	(0.055)***
Expected Log of Total Fine	-0.051	-0.051
	(0.026)**	(0.026)**
Individual Discount Rate	0.100	0.047
	(0.020)**	(0.020)**
Log (Age of skipper)	-0.255	-0.264
	(0.095)**	(0.095)***
Log (Wealth of skipper)	0.003	0.005
	(0.027)	(0.027)
Dummy for *Ownership* (=1 if skipper owned; 0 otherwise)	0.075	0.072
	(0.054)	(0.055)
Dummy for *Exogenous Factors Leading to Declining Stock*	-0.112	-0.109
	(0.057)*	(0.057)*
Dummy for *Social Pressure*	0.333	0.313
	(0.120)***	(0.120)***
Dummy for *Regulation Protects Well-being*	-0.046	-0.066
	(0.036)	(0.030)**
Dummy for *Regulation Protects Stock*	0.017	
	(0.042)	
Dummy for *Regulation is a Right Thing*	-0.066	
	(0.044)	
Dummy for *Regulation is Fair*	-0.034	-0.047
	(0.028)	(0.027)*
Constant	1.711	1.740
	(0.412)***	(0.416)***
Observations	298	298
Adjusted R-squared	0.20	0.20

Note: Standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Since very few boats (i.e. less than 1%) did not fish with the net with small mesh size, the Ordinary Least Square (OLS) estimation procedure was employed to estimate the intensity of violation equation. To check for robustness, the Tobit estimation procedure was also used and the results were similar. The results of the estimation of the intensity of violation equation are shown in Table 2. The second column of the table (i.e. the column with subtitle (1)) presents the results that include all the perception variables. However, due to the strong correlation among the variables, which was also reported in Hatcher et al. (2000), and Hatcher and Gordon (2005), we included two out of the four in the estimation and the results are reported in the last column (i.e. the column with subtitle (2))[xi]. Since it is possible that the subjective probabilities are endogenous, Glejser's test was employed to verify this possibility (see Mukherjee et al., 2003 for the description of the test). The test involves regressing absolute residuals on each of the suspected endogenous variables (i.e. the probabilities) and the slope coefficient examined. If the slope coefficient is statistically significant, then the variable under consideration is endogenous. From the test statistics, we failed to reject the hypotheses that the probabilities were exogenous.

The traditional variables, i.e. the subjective instantaneous conditional probabilities of detection and arrest given detection, and expected fine, are significantly different from zero at the 1% level of significance and have the expected signs. The respective elasticities are 0.127 and 0.122 in the first equation, and 0.129 and 0.128 in the second equation. This implies that a one percent increase in the probability of being detected, given that the violator had escaped detection in the past, will decrease the intensity of violation by 0.127% and 0.129% in the first and second equations respectively. Furthermore, a one percent increase in the probability of arrest, given that the violation is detected and the violator has escaped arrest in the past, will decrease the intensity of violation by 0.122% and 0.128% in the first and second equations respectively. Thus, the negative sign implies that the intensity of violation could be reduced, *ceteris paribus*, if inspection and arrest for violating the mesh regulation are increased. The mean value of the probability of detection is higher than that of arrest given detection, but the elasticity coefficients are the reverse, which is consistent with earlier findings (See e.g. Furlong, 1991).

The elasticity of the expected log of fine of 0.051 indicates that a one percent increase in the severity of punishment is likely to reduce intensity of violation by 0.05%[xii]. The value is however lower than that of the probabilities, implying that increasing the risk of detection will have a higher likelihood of reducing violation relative to increasing the severity of punishment. These low values are likely due to poor monitoring and enforcement or the regulation.

The coefficient of the discount rate is positively related to the intensity of violation and significantly different from zero at 5% level of significance[xiii]. The positive coefficient of the rate implies that the more impatient fisher has higher intensity of violation of the mesh regulation. There have been numerous empirical findings that have established a positive relationship between poverty or hunger and individual discount rates (see for example Holden et al., 1998), and since artisanal fishers are known to be poor, this finding is not unexpected. The elasticity coefficient for the individual discount rate is higher than that of the risk and severity of punishment, which implies that by advancing any policy that reduces the discount rate among the artisanal fishers, intensity of violation is likely to decrease much more than increasing either the risk or severity of punishment.

Table 3: Ghana-Estimated Elasticities of the Determinants of Intensity of Violation of Mesh Size Regulation (Evaluated at the Mean)

Variable	(1)	(2)	Mean of Variable
Probability of Detection	0.127	0.129	0.610
Probability of Arrest Given Detection	0.122	0.128	0.635
Expected Log of Total Fine	0.051	0.051	0.810
Individual Discount Rate	0.131	0.121	1.311
Social Pressure	0.236	0.221	0.707
Age of Skipper	0.255	0.264	40.68
Dummy for Exogenous Cause of Stock Decline	0.055	0.054	0.490
Dummy for Fairness of Regulation		0.111	2.346
Dummy for Well-being		0.120	1.819

The variables for legitimacy and feasibility of rule and fairness are not significantly different from zero in the extended equation (i.e. second column of Table 2), because of the strong correlation problem mentioned earlier. However, each of the variables is statistically significant if it is included in the regression alone. In the last column of Table 2, the dummies for *well-being* and *fairness* were included and they were both statistically significant.

Moreover, *social pressure* was consistently significantly different from zero, indicating that the skippers' perception about compliance behavior of other fishers influences the intensity of their compliance behavior. The elasticity coefficient of social pressure is the second highest. Since social pressure is measured as the fishers' perception of the proportion of fishers who violate the regulation, it follows that by reducing the level of non-compliance, compliance further increases. Thus, all the social factors were very significant in explaining compliance with the mesh size regulation.

An interesting finding from the data is that skippers who were aware that their intensive fishing activities were responsible for declining stock had, on the average, higher intensity of violation with elasticity coefficient that is about the same as that of the expected fine. Thus, providing information to the fishers about the impact of overfishing on the stock will rather increase competition for the resource. Furthermore, the younger skippers had higher intensity of violation of the regulation, with a highest elasticity coefficient of about twice that of the risk of detection.

CONCLUSION

This study does not only provide additional empirical support for the standard theory of criminal behavior but also highlights the importance of individual discount rate in violation of fishing regulations. It was found that the more impatient fishers had higher intensity of violation, with elasticity coefficient of the discount rate that exceeded that of risk and severity of punishment. It follows that, by addressing the underlying causes of high discount rates among the artisanal fishers, significant reduction in the intensity of violation is likely to be achieved. Based on the strong effect of the discount rate on the intensity of violation, we recommend that future empirical research on regulatory compliance in fisheries that are committed repeatedly may have to incorporate individual discount rate.

Furthermore, the risk of punishment, i.e. instantaneous conditional probabilities of detection and of arrest given detection, and the severity of punishment, i.e. expected fine, were found to be statistically significant and negatively related to the intensity of violation. However, the intensity of violation is more responsive to the risk of punishment than the severity of punishment. By implication, the Fisheries Department should direct more resources to surveillance and arrest of violators of the mesh size regulation. Moreover, since the younger skippers have high intensity of violation, the Department should focus on them relative to the older ones.

The violator's perception of social pressure was positively related to intensity of violation. Also, legitimacy and feasibility of the regulation were important in explaining compliance behavior. Skippers who indicated that the regulation is not legitimate or feasible had higher intensity of violation. This implies that the compliance rate is likely to improve if the management authorities intensify education of fishermen about the destructive consequences of the illegal nets, all other things being equal. On the other hand, the violators who indicated that the general decline in the trend of the fish stock was not caused by fishing activities of the artisanal fishers, on the average, had lower intensity of violation. Conversely, violators who were aware that overfishing was responsible for the declining stock rather had high competition for the stock. The implication is that providing the artisanal fishers with information on the impact of their fishing activities on the stock may be counter-productive since it is likely to result in intensification of violation of the mesh size regulation. However, from the relative elasticities of these two opposing factors, there is potential net benefit from providing such information to the fishers.

Wealth and ownership were not significant in our regression. One reason why wealth was not significant could be that the fishers did not want to reveal their true wealth for fear of theft. Indeed most of them were not comfortable with the questions relating to their wealth.

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Endnotes

[i] If the violator can predict the trend of future harvests, then the problem becomes a stochastic dynamic problem with equation (3) as the objective function, and equation (4) and the stochastic stock evolution equation are the constraints.

[ii] Note that equation (6) can be re-specified as $V^{i1}(y) = \left[(1-G)d^i(y_i) - gq_iF\right]_i \Big/ \left(\delta_i + p(y_i)\right)(1-G)$ so that the numerator is a discrete time analogue of $(1-b)d^i(y_i) - bq_iF$, where b is the probability of detection. Consequently the basic difference between the discrete and continuous time representation is that, in the dynamic model, the flow of the returns is sustained until detection, hence the probability in the static model is replaced by the conditional probability.

[iii] For example, after a sharp increase in catch per unit effort (CPUE) (i.e. catch per boat) from 27.4 from 1989 to 35.3 in 1992, it declined from 1992 through 1995. Although the CPUE increased by 42.4% from 1995 to 1996, it was still lower than the 1992 level. The lowest figure of 23.6 was in 2001, which was the latest available data (Atta-Mills et al., 2004).

[iv] In a village, the chief fisherman enforces local fishing norms and has the power to punish if the norms are not obeyed.

[v] The responses to a question about the level of confidence in the chief fisherman in regulating fishing activities within the district indicated that over 91% of the fishers interviewed had great deal of confidence in him.

[vi] When fishermen land their catch, juvenile fishes are sorted and sold separately so it is easy to collect the data on the disaggregated catch.

[vii] The five-point scale of the probabilities is: very high (0.5 or more), high (around 0.25), quite possible (around 0.10), moderately low (around 0.05), and very low (0.01 or less).

[viii] Since loans are contracted on very short term (say monthly) basis, δ approximates $n\ln(1+rn^{-1})$ if n is large, where n is the number of times the interest on the loan compounds in a year and r is the discrete time annual interest rate.

[ix] Aryeetey (1994), also found a very high informal quarterly lending rates of about 25-30%. If this rate compounds, the corresponding annual lending rate is 127-134%, which is very close to what has been found in this research. Note that the high rate may be due to high rate of default coupled with high and volatile rate of inflation.

[x] Since six observations were zeros, we added one to each observation and then took the logarithm. By doing this, the observations with zeros are maintained after the log transformation so that the Tobit estimation procedure could be employed to check for robustness of the Ordinary Least Square results.

[xi] A pairwise correlation coefficient test indicates that all the variables are correlated at 5% level of significance.

[xii] Note that the elasticity of intensity of violation with respect to total fine, if evaluated at the mean value of the probability of being fined given arrest of 0.1001, is 0.005, which is very low.

[xiii] In order to check for any significant effect of extreme values of the individual discount rate on its coefficient in the regression, the rates were ranked from 1 to 5 based on its frequency distribution. The coefficients did not change.