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ESSAYS ON ECONOMICS OF NATURAL RESOURCE MANAGEMENT AND EXPERIMENTS

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Abstracts

This thesis has five self-contained essays. The titles and the abstracts of the various essays are as follows.

Paper 1: Natural Resource use Conflict: Gold Mining in Tropical Rainforest in Ghana

Gold is frequently mined in rainforests that can provide either gold or forest benefits, but not both. This conflict in resource use occurs in Ghana, a developing country in the tropics where the capital needed for mining is obtained from foreign direct investment (FDI). We use a dynamic model to show that an ad valorem severance tax on gross revenue can be used to internalize environmental opportunity costs. The optimal tax must equal the ratio of marginal benefits from forest use to marginal benefits from gold extraction. Furthermore, the tax should increase (decrease) when adjusted net return on all other assets in the economy is higher (lower) than the growth in the price of gold. Empirical results suggest that the 3 percent tax rate currently used in Ghana is too low to fully represent the external cost of extraction (i.e., lost forest benefits).

Paper 2: Dynamic Model of Regulatory Compliance in Fisheries: The Case of Mesh Size

This paper employs a dynamic model for crimes that involve time and punishment to analyze the use of nets with illegal mesh size under two management regimes: competitive and regulated open access fishery. The model is based on the consideration that the illegal net is used repeatedly until detection; the net decreases the expected weight recruitment of catchable fish; and lowers the average cost of harvest. We find that under the competitive fishery, the equilibrium stock and harvest are lower if the fishers use the illegal mesh size. However, under regulated open access, the size of the equilibrium stock depends on the ratio of the elasticity of catchability coefficient to the elasticity of the hazard rate. Furthermore, under some condition, the fine for violation should be higher under open access relative to the competitive fishery for any given level of violation.

Paper 3: Individual Discount Rate and Regulatory Compliance in a Developing Country Fishery

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.

Paper 4: Does Ostracism Decrease Over-fishing? A Common Pool Resource Experiment in Ghana

This paper investigates how the presence of ostracism, which is a familiar punishment mechanism to the subjects in an experiment, affects harvest in a common pool resource experiment. The experiment was framed as a fishing problem and the subjects were young fishers in Ghana. We find that the introduction of the possibility to ostracize other members of a group at a cost to the remaining members of the group decreased over-fishing significantly in comparison to the case where ostracism was not possible. Moreover, the subjects demonstrated a strong desire to ostracize those who over-fished.

Paper 5: The Environment as a Public Good and Internalized Contribution Norms

This paper links a utility theoretical model based on internalized norms, influenced by Bowles and Gintis (2005), with the results from a novel public goods experiment in Ghana. The results indicate that, on average, people are motivated by conditional cooperation of two kinds: people want to contribute more if others have contributed more in the previous round, and people want to contribute more if others are expected to contribute more. We also found evidence of learning, in the sense that people's contribution decrease over time even if others' contribution is held constant.

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The quest for deeper understanding of economics of fisheries took me to the Center for Fisheries and Aquatic Management and Economics (FAME), an incredible institute, where I met and interacted with inspiring individuals like James Wilen, Jon Sutinen, Ragnar Arnason, Niels Vestergaard, Susan Hanna, and Heine Ruppert. I feel honored to be a part of the FAME family.

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Wisdom Akpalu
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Contents

Introduction

It has been noted that while environmental preservation, including sustainable management of renewable natural resource, may be a luxury for the rich, it is a bare necessity for the poor (Parikh, 1998). In Ghana, as in many developing countries, the poor depends heavily on natural resources, such as rainforest and wild fish stocks. It is estimated that as high as 40% of the population of Ghana live below the poverty line and 27% in extreme poverty (Ghana Statistical Service, 2000). With very fast depletion of these renewable natural resources, the need to adopt adequate resource management strategies in order to save the poor has become very apparent. This thesis, which has five self contained essays, seeks to address some resource management problems in Ghana and also investigate the role of endogenous institutions and internalized norms in social dilemmas.

In the first essay, we address a natural resource-use conflict, i.e. gold mining in tropical rainforest in Ghana. Gold deposits are found in tropical forests that can provide in situ benefits to rural populations if the gold beneath them is not extracted. Moreover, the capital needed for mining is obtained from foreign direct investment (FDI). We use a dynamic model to show that an ad valorem severance tax on gross revenue can be used to internalize the environmental opportunity costs, i.e. non-timber forest benefit loss.

In the second and third essays, we investigate compliance with mesh size regulation in a developing country fishery. Specifically, in the second essay, a dynamic model for crimes that involve time and punishment was developed to analyze the use of nets with illegal mesh size under competitive and regulated open access fishery. Drawing on data from an artisanal fishery in Ghana, the third essay provides an empirical support for the dynamic model by considering a fishery crime that generates flow of returns until the offender is caught and then punished. Thus, we incorporate into the existing one-period model, the influence of dynamic deterrence, which depends on the rate of time preference.

Furthermore, with low budget of central government to enforce fishing regulations, community-based fishery management has been encouraged in Ghana. Thus, communities are encouraged to draft fishing laws to manage their fishery. Moreover, the efficacy of these endogenous regulations depends on the willingness of individuals within the communities to enforce the regulations at the community level. The fourth essay, therefore, investigates how the presence of ostracism, which is a familiar punishment mechanism to the subjects in an economic experiment, affects harvest in a common pool resource experiment. The experiment was framed as a fishing problem and the subjects were young fishers in Ghana.

Finally, in the absence of laws of appropriation, individuals find themselves in a dilemma of satisfying their self-interest or conforming to the social interest. In the last essay, we link a utility theoretical model based on internalized norms with the results from a novel public goods experiment with university students as our subjects.

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Paper 1

Natural Resource use Conflict: Gold Mining in Tropical Rainforest in Ghana

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Abstract

Gold is frequently mined in rainforests that can provide either gold or forest benefits, but not both. This conflict in resource use occurs in Ghana, a developing country in the tropics where the capital needed for mining is obtained from foreign direct investment (FDI). We use a dynamic model to show that an ad valorem severance tax on gross revenue can be used to internalize environmental opportunity costs. The optimal tax must equal the ratio of marginal benefits from forest use to marginal benefits from gold extraction. Furthermore, the tax should increase (decrease) when adjusted net return on all other assets in the economy is higher (lower) than the growth in the price of gold. Empirical results suggest that the 3 percent tax rate currently used in Ghana is too low to fully represent the external cost of extraction (i.e., lost forest benefits).

Summary

The location of gold deposits within valuable natural environments imposes a dilemma that requires an exchange of future benefits from the environments for current benefits from extracted gold. A profit tax – one based on net revenues from extraction – will not usually change the optimal rate of extraction. However, an ad valorem severance tax – one based on gross revenues from extraction – will usually change this rate (e.g., Dasgupta and Heal, 1979; Hanley, Shogren and White, 1997). Because severance taxes are widely used in practice, it is fortunate that this distortionary effect can be harnessed to internalize the opportunity costs of environments that are lost or damaged during the gold extraction process. This paper presents the details of an efficient severance tax, and illustrates such a tax using data for gold mining in Ghana's rainforests.

Our approach must differ in two important ways from classic extraction problems examined by Hotelling (1931) and many subsequent authors. First, gold deposits in Ghana are found in tropical forests that can provide in situ benefits to rural populations if the gold beneath them is not extracted. Second, the capital needed for gold extraction is derived from foreign direct investment (FDI). The former difference will require forest benefits to be considered, while the latter will require that profits from gold extraction be no less than zero.

By extending the literature on sharecropping, we formulate and derive results from a dynamic optimization program for the mining firm (the tenant) and the resource manager of the country (the landlord). The mining firm maximizes a discounted stream of profits from extracting gold. Revenue per unit extracted is equal to the gold price minus the severance tax, subject to the rate of the gold stock depletion. The resource manager, on the other hand, maximizes the discounted sum of tax revenues and benefits from the forest stock, subject to depletion in the gold and forest stocks, and a profit constraint that requires mining in each period to at least break even.

We find that a severance tax can be used to lead mining firms to choose gold extraction that also is optimal for the manager's extraction problem, if the tax is set equal to the

ratio of marginal forest benefits to marginal benefit from gold extraction. The optimal tax must change at a rate equal to the difference between the discount rate and rate of change in the price of gold. The optimal tax is positively related to the discount rate and negatively related to the price of gold. Empirical simulations suggest that the current 3 percent tax rate is too low to fully represent the external cost of extraction (i.e., lost forest benefits). We conclude that ignoring environmental opportunity costs of extraction when selecting the tax rate may lead to irreversible loss of forest ecosystems. Because similar conflicts are common in other tropical countries, the results from this Ghanaian analysis may cautiously be extended to other natural resources in developing countries.

1.1 Introduction

Gold, diamonds, and other precious minerals are extracted from rainforests found in numerous developing countries. Resource use conflicts are common, but models of these conflicts are uncommon. Among the exceptions are Ehui and Hertel (1989), Ehui et al. (1990) and Swallow (1994), who study interactions between non-renewable and renewable resource uses. Swallow (1994) examines the relationship between wetland development (i.e. non-renewable resource extraction) and preservation of the wetland for shrimp production (i.e. renewable resource). Ehui et al. (1990) present a theoretical model to determine socially optimum size of tropical forest reserve, when land may be either cleared for agriculture or preserved as forest. The forest in this study is treated as a non-renewable resource, and extraction of it makes land available for agriculture (Hanley et al., 1997).

It has been known for decades that a severance tax decreases per unit revenue, and consequently increases cut-off grade of minerals or decreases optimal extraction of minerals (e.g., Hotelling, 1931). The tax has the same effect as an increase in average cost of extraction (Dasgupta and Heal, 1979). It is not surprising that such ad valorem severance taxes are usually opposed by mining firms. Most mining firms in developing but resource-rich countries assert that these taxes increase extraction costs such that a significant portion of the nations' mineral endowment will never be mined (e.g., Chamber of Mines of South Africa, 2002/2003).

To the best of our knowledge, no theoretical model exists on the tradeoff between gold deposits (i.e. non-renewable resource) and rainforests within which the deposits are found (i.e. non-renewable resource) in a country that has foreign capital in mining. As a share contract, the mining firm provides the inputs required for the mining activities and gives a fixed fraction of the total revenue to the gold-rich country. Following Ehui et al. (1990), we employ dynamic optimization techniques to model the tradeoff between gold deposits and rainforests, with Ghana as a case study. By requiring the firm's profits each period to be nonnegative, we show that Ghana's present severance tax may lead to efficient extraction if it is dynamic and includes forest benefits lost due to extraction.

The growth rate of the tax is the difference between the rate of interest and rate of change in the price of gold.

The next section gives a brief description of gold extraction in Ghana before and after the national mineral policy, and describes several of the known benefits obtained from the rainforest if gold is not extracted. This is followed by an economic model of extraction in section 1.3. Section 1.4 presents an optimal severance tax, and Section 1.5 describes changes in the optimal tax using comparative statics. Section 1.6 describes the application of the model with empirical information from Ghana, and Section 1.7 concludes.

1.2 Gold Mining and Deforestation in Ghana

Gold mining has been an important source of foreign exchange in Ghana since her independence in 1957. In a bid to provide employment, control the rate of extraction, and generate foreign exchange, the state controlled the mining industry from 1957 to 1986, by owning majority shares of over 55% in the major mining companies (Tsikata, 1997). Inadequate macroeconomic policies – such as an overvalued exchange rate – diminished the funds available to maintain and rehabilitate the mining industry (Aryeetey et al., 2000). The mining industry faced under-capitalization and low efficiency due to poor management and weak mining skills. Gold extraction was very low, decreasing from 915,317 ounces in 1960 to the lowest level of 287,124 ounces in 1986 as per Figure 1.

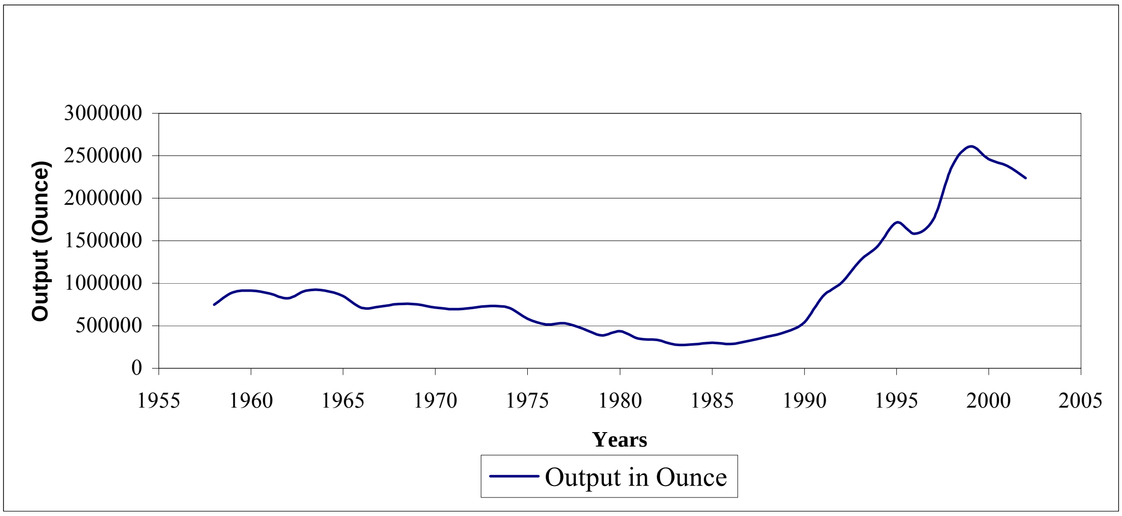

Figure 1: Trends in Gold Production in Ghana Before the Mineral Sector Reform (1958-1986) and After the Mineral Sector Reform in 1986 (1987- 2002).

Beginning in 1986, as part of the Economic Recovery Program sponsored by the International Monetary Fund, there was a shift from state ownership to liberalization, deregulation, and privatization of the mining sector. Mining aspects of this Program were intended to help improve efficiency and raise much needed foreign exchange. A specific requirement of the National Mineral Policy of 1986 was to relax several mining policies. With the revision of the policies, government revenue from the extracted gold was restricted to 3-12% royalty tax, and corporate tax of 35%. In addition, the mining industry was not subject to environmental regulations until 1994, when the Environmental Protection Agency (EPA) Act was passed by Parliament (EPA Act, 1994 (Act 490)). The EPA Act required Environmental Impact Assessments and Environmental Management Plans to be prepared by all new and existing mining firms (Akabzaa and Darimani, 2001). In practice, lack of resources has limited the enforcement of these provisions.

This drive dramatically increased foreign direct investment (FDI) from $12.8 million in 1986 to $83 million in 1998 (Addy, 1998). Gold production eventually overtook the 1960 peak levels, and reached a record high of 2,481,635 ounces in 1998. By 1994, gold exports generated the highest export earnings (about 45% of total earnings), surpassing cocoa, which had been the leading commodity for export earnings (Akabzaa and Darimani, 2001). Figure 1 shows the general increasing trend of production.

However, this increased production had negative consequences on the environment. The surface mining technologies used to extract rainforest gold led to annual deforestation rates of roughly 2 million acres. By 2001 over 60% of the rainforest in Wassa West District (a typical gold mining district) was lost to gold mining activities (Tockman, 2001). It is estimated that only 12% of the country's rainforest remains, with surface gold mining the main cause of deforestation (Ismi, 2003).

Ghana's extremely heterogeneous tropical rainforest provides a wide range of benefits. For example, it is estimated that more than 75% of the protein in West Africa comes from bush meat (Asibey, 1974; Benhin and Barbier, 2004). The bush meat trade supports about 300,000 people in rural areas, out of which 270,000 are self-employed hunters. Annual harvest is estimated at 385,000 tons, worth over $350 million. Of the annual harvest, 225,000 tons, worth $205 million, are locally consumed (Fobi, 2003). In addition, 70% of Ghanaians depend only on traditional medicine for health care. Traditional medicines are derived from roughly 2000 plants (Zhang, 2001) which are also exported to Europe for the production of medicine (Benhin and Barbier, 2004). Furthermore, many forest products are used as raw materials in household and local production of baskets, furniture, roofing materials, musical instruments, jewelry, hunting tools, traditional drums, and other items. Major rivers such as the Birim, Pra, Ankobra, Bonsa Offin, Densu, and Tano, which provide drinking water to many towns and cities, are fed by rivers and streams that run through all the forest reserves (Anane, 2003).

Regarding biodiversity, the Ghanaian forest is home to several rare species of fauna and flora, the populations of which are declining due to rapid destruction of forest habitats. Some of the rare animal species include giant forest hogs, primates, bongo, small antelopes, small bats and rodents, and birds. In addition, forest elephants disperse seeds of important timber species and create tracks for white-breasted guinea fowls. The International Union for Conservation of Nature and Natural Resources (IUCN) database has noted ten timber species in Ghana to be of conservation concern (Benhin and Barbier, 2004). Unfortunately, these benefits are completely overlooked when concessions are granted to mining companies.

1.3 The Model

In many non-renewable resource-rich countries, a fraction of the value of the extracted resource is taxed by the state to compensate for the opportunity cost of the extracted resource. In Ghana, all minerals are owned by the state, and the tax for gold extraction is between 3% and 12% of the gross value. The minimum tax of three percent is most commonly charged (Akabzaa and Darimani, 2001). This tax approach is often preferred, because it guarantees a share of extraction revenues (e.g., Ranck, 1985; Hanley et al., 1997). Because this approach is similar to that of a landlord and tenant farmer, we extend a sharecropping contract model (Cheung, 1968), with the mining firm as tenant, and the resource-rich country as the landlord. The basic model must be made dynamic, and extended to include forest opportunity costs, since the mining companies do open-pit or surface mining in the rainforest (Akabzaa and Darimani, 2001).

Several features adapt the model to the Ghanaian empirical context. First, because a small part of the world's gold is produced in Ghana, we treat the domestic mining market as perfectly competitive. Second, because surface mining involves some of the lowest costs, virtually all firms use this extraction strategy. To reflect this trend, we treat all firms as identical. Third, by the end of 1999, the inflow of FDI to Ghana's mining exceeded $3 billion (Akabzaa and Darimani, 2001), roughly 147% of that year's GDP. Consequently, we assume that capital used in mining is from FDI. To streamline the model, the mining firm and the resource manager use the same rate of time preference; mining is done in forest reserves where logging is not permitted; and gold is uniformly distributed beneath the forest cover.

1.3.1 The Resource Country or Social Planer's Problem

The surface mining method used by the gold mining firms in Ghana removes the rainforest where the deposits are found, leaving open pits and valleys (Akabzaa and Darimani, 2001). After mining, the land is typically no longer usable for agriculture. As noted earlier, the nation's rainforest provides infinite stream of direct non-timber forest benefits such as provision of wild fruits, tubers, and cereals for human consumption; serving as breading ground for mammals that are hunted for animal protein; supporting rivers and streams that provide drinking water, among others. When gold is extracted by a mining firm, the total surplus that accrues to the country consists of total tax revenue (i.e. θpy) plus non-timber benefits from the remaining total forest stock (i.e. $a(f)$), where θ is a tax rate, p is exogenous world price of gold, y is quantity of gold extracted by a mining firm within a particular year, f is the remaining forest stock/cover in the area allocated to the miner and $a(f)$ is the general functional form of non-timber forest benefits to the society from this forest stock. The country's social planner therefore chooses a time path that maximizes the stream of surpluses given by equation (1), subject to equations of motion of gold stock depletion ($\dot{x}$), forest stock depletion ($\dot{f}$), and a non-negative discounted stream of profit constraint of the firm. The gold and forest stock depletion equations are first order differential equations. The linear relationship between the rate of deforestation and the quantity of gold extracted is assumed for simplicity.

$$\underset{\{\theta,y\}}{Max}\int_0^T [\theta py + a(f)]e^{-rt}dt\,, \tag{1}$$

Subject to:

(2)

a) $\dot{x} = -y$

b) $\dot{f} = -\dfrac{1}{\alpha}y$

c) $\int_o^T \left[(1-\theta)py - c\left(y\right)\right]\mathrm{e}^{-rt}\,dt \ge 0$

$x \ge 0$, $y \ge 0$, $f \ge 0$, $f(0) = f_0$ and $x(0) = x_0$.

Where $c(y)$ is the cost function of a firm and t is time, e.g. in years. The cost depends on only the harvest (see Conrad, 1999 for an example). The following partial derivatives: $c_y > 0$, $c_{yy} > 0$ hold; r is a positive net benefit discount rate, which we assume to be equal to the social rate of time preference. It is positive because the firm will prefer a given amount of benefit today to the future. T is the end of the extraction period. We assume that non-timber forest benefits increase in the size of forest stock at a constant rate, hence $a_f > 0 \quad and \quad a_{ff} = 0$. Furthermore α is the coefficient of gold yield per acre of the deforested land.

Because we assume there is no exploration for gold, the equation of motion defines the rate of depletion, which is the flow without backstop. Also, since tropical rainforest loss is irreversible, we model the forest stock depletion as a non-renewable resource as per the equation of motion (see Ehui and Hertel, 1989, and Ehui et al., 1990 for a similar presentation). Since the capital comes as FDI, the direct cost of mining has no opportunity cost to the country and is not included in the objective function. Thus, the constraints to equation (1) are the stock depletion equations given by (2a) and (2b), and the additional constraint, which guarantees that the discounted net revenue from mining over the entire period is non-negative (equation (2c)).

The current value Hamiltonian associated with equations (1) and (2a, and b) is

$$H^C(y, f, \lambda, \mu, \theta, t) = \theta py + a(f) - \frac{\mu}{\alpha} y - \lambda y \tag{3}$$

Where μ and λ are the user cost associated with total forest and gold stocks, respectively. Since equation (2c) is an additional constraint in isoperimetric form (see Doherty and Posey, 1997; Caputo, 1998, 1999 for some examples of Isoperimetric constraints), we extend the current value Hamiltonian to

$$H^C(y, f, x, \lambda, \mu, \psi, \theta, t) = \theta py + a(f) - \mu \frac{1}{\alpha} y - \lambda y + \psi[(1-\theta)py - c(y)] \tag{4}$$

Assuming some quantity of gold is extracted at every point in time (i.e. existence of interior solution), the static efficiency conditions, which are the first order derivatives of the Hamiltonian function with respect to the flow variable y and the choice variable θ are equations (5) and (6), respectively:

$$p - c_y - \frac{1}{\alpha}\mu - \lambda = 0 \tag{5}$$

$$\psi = 1 \tag{6}$$

Note that ψ is not a shadow price but a multiplier associated with a constraint that is measured in the unit of price. Further, it takes the value 1 on the optimal path indicating that the additional constraint will hold for the representative firm within the entire mining period. In other words if the firm does not break-even it will relocate or fold up. In Ghana, there is evidence of threat by gold mining firms to relocate to countries with friendlier policies (Ismi, 2003). We derive some important results from the preceding equations.

Since λ and μ are user costs faced by the mining firm, we have a modified non-distortionary static efficiency condition. The rule postulates that under perfect competition the marginal profit from the extracted gold will equate the user cost of the resource. In this particular case the rule is modified because the user cost include both the user costs of the resource on a bare ground (λ) and that of the gold yield of the forest stock ($\frac{1}{\alpha}\mu$). The equation defines the desired inter-temporal extraction condition of the social planer. Any deviation of the firm from this optimal path condition is undesirable to the planer. Equation (5) can be rewritten as

$$p - c_y = \lambda + \frac{\mu}{\alpha} \tag{7}$$

From microeconomic theory, if marginal damages are considered, the marginal social cost becomes higher than the private cost leading to an efficient level of output which is lower than otherwise. Consequently, if forest stock effect is neglected, the marginal profit will equate only the user cost of the gold stock and result in over extraction.

The portfolio balance or costate equations are:

$$\dot{\lambda} - r\lambda = 0 \tag{8a}$$

$$\dot{\mu} - r\mu = -a_f \tag{9}$$

Equation (8a) is the costate equation of the stock of gold associated with the social planer's problem, which involves only the equation of motion of the stock of gold. Thus, the decision to mine the resource depends on marginal benefit from harvesting the resources and depositing the revenue at the net benefit discount rate on one hand (i.e. $r\lambda$), and the marginal opportunity cost, which is the marginal benefit from the growth in the rental rate (i.e. $\dot{\lambda}$), on the other hand. Conversely, the return on all other assets in the resource-rich country (i.e. *r*) equals the growth in the shadow price per ounce of gold (i.e. $\frac{\dot{\lambda}}{\lambda}$). Equation (9) stipulates that on the optimal path, the return on all other assets in the economy (*r*) equals the growth in the shadow price per hectare of the forest stock ($\frac{\dot{\mu}}{\mu}$) plus the value of the loss in marginal benefits of the forest stock adjusted by the shadow price of the forest stock ($\frac{a_f}{\mu}$) (Krautkraemer, 1988). Since we have stock effect in the objective function, the optimal path condition given by equation (7) could be used to determine the appropriate tax to be levied on the firm.

1.3.2 The Miner's Problem

The representative miner chooses an extraction path that maximizes the net present value of profits (i.e. equation 10) with revenue constituting a fraction of the total proceeds from the sale of gold ($(1-\theta)py$), and cost of production as a function of the harvest of gold (i.e. $c(y)$), subject to the equation of motion of the stock of gold. The discounted stream of net revenue or profit function is[1]:

$$\underset{\{y\}}{Max}\int_0^T \big((1-\theta)py - c(y)\big)e^{-rt}dt, \tag{10}$$

[1] The profit function is concave. From equation (12), $(1-\theta)p - c_y = \lambda > 0$ and $-c_{yy} < 0$. Where c_y is partial derivative of the cost function with respect to y.

Subject to equation (2a), $x \geq 0$ and $x(0) = x_0$.

The current value Hamiltonian is:

$$H^c(y, \lambda, t) = (1-\theta)py - c(y) - \lambda y \tag{11}$$

The associated Pontryagin maximum principle and the costate equation, which define the static and dynamic efficiency conditions, are equations (12) and (8b), respectively. If some quantity of gold is extracted every year, then:

$$(1-\theta)p - c_y = \lambda \tag{12}$$

$$\dot{\lambda} - r\lambda = 0 \tag{8b}$$

From the static efficiency condition, at each point in time the marginal profit from harvesting the gold (i.e. $(1-\theta)p - c_y$) is equal to the firm's user cost of the remaining gold stock (i.e. λ). Equation (8b), just as equation (8a), establishes production decision based on optimal path relationship between the marginal benefits from harvesting the gold today and in the future.

Since the terminal time of the firm's optimization program is free, equations (4) and (11) must equal to zero at $t = T$ (i.e. $H^c(T) = 0$). Thus, at the end of the planning horizon, the mine shuts down and extraction ceases (Conrad and Clark, 1995). From equation (12), the optimal inter-temporal extraction policy is $(1-\theta)p - c_y = \lambda(T)e^{r(t-T)}$ for all $t \leq T$. On the other hand, in the absence of the tax, the corresponding inter-temporal extraction policy is $p - c_y = \lambda(T)e^{r(t-T)}$ for all $t \leq T$. This implies that for all $t \leq T$, lower quantity will be extracted if the tax is imposed compared to what will prevail in the absence of the tax, a clear indication of distortionary effect of the tax.

If we compare the static efficiency conditions for the mining firm and the resource-rich country (i.e. equations (5) and (12)), it follows immediately that the firm will not follow the optimum path desired by the gold-rich country if the forest stock depletion is not internalized. The divergence comes from the difference between the tax received (θp) and marginal damage to the rainforest ($\frac{\mu}{\alpha}$).

1.4 Economic Policy Instrument

If the mining is done on a bare ground, any positive value of θ will be distortionary simply because the user cost of gold from the inter-temporal efficiency condition of the social planner cannot equate that of the firm (i.e. $1 > (1-\theta)$, since $p - c_y > (1-\theta)p - c_y$). Consequently, the tax is not a desirable economic policy instrument for raising revenue without decreasing the optimal path levels of extraction for all $t \leq T$: a condition that is well established in the literature (see, e.g., Dasgupta and Heal, 1979). Nevertheless, since mining destroys rainforest, the distortionary effect disappears with optimal value of the tax rate.

Proposition 1:
The optimal tax equals the ratio of marginal forest benefit to marginal gold benefit. And the current value of the user cost of the forest equals its initial value plus some adjustment for changes in the marginal non-timber forest benefit.

The proof for the above proposition is as follows. If we compare the optimal path of the social planer (i.e. $p - c_y - \frac{\mu}{\alpha} = \lambda$) and the firm (i.e. $(1-\theta)p - c_y = \lambda$), an expression for a corrective tax can be derived. Following Parks and Bonifaz (1994), the tax expression is the difference between the two equations as

$$(p - c_y - \frac{\mu}{\alpha}) - ((1-\theta)p - c_y) = 0 \;\Rightarrow\; \frac{\mu}{\alpha} = \theta p \tag{13}$$

Clearly the difference between the two equations is $\frac{\mu}{\alpha} - \theta p$. Equation (13) simply equates the average tax revenue (θp) to the user cost of the gold yield of the forest stock ($\frac{\mu}{\alpha}$) on the optimal path[2]. If $\frac{\mu}{\alpha} - \theta p > 0$ then the tax rate is too low and as a result, the optimum path of the firm will be higher than what is socially desired. On the other hand if $\frac{\mu}{\alpha} - \theta p < 0$, which is the case if the social planner charges the tax for losing the gold and the forest, then the firm's path will be too low. The optimal tax should therefore equate the marginal damage to the forest. Thus the tax could be used to correct the extraction externality. The appearance of the user cost of the forest stock in the tax equation is consistent with Pigou (1946) and Hanley et al. (1997), among others. Furthermore, the royalty tax is a function of time (see Löfgren, 2003 for an example).

From equation (9) since $a(f)$ is a linear function, the time path of $\mu(t)$ yields equation (14),

$$\mu(t) = \mu_0 e^{rt} + \left(1 - e^{rt}\right)\frac{a_f}{r} \tag{14}$$

Where $\mu_0 e^{rt}$ is the initial marginal value of the forest stock valued at current price, the last two terms (i.e. $\left(1 - e^{rt}\right)\frac{a_f}{r}$) is some adjustment for the change in the marginal non-timber forest benefits valued at current price, a_f and μ_0 are positive constants. The assumption of $\mu_0, a_f > 0$ is based on the fact that the forest cover in resource-rich countries are highly depleted. Moreover the scarcity value of the forest stock will be

[2] Moreover, the royalty tax is open but bounded between zero and one. From equations (5) and (13): $0 < \theta = \frac{\mu}{\alpha p} = \frac{\mu}{\mu + \alpha\lambda + \alpha c_y} < 1$ for all non-negative values of λ and c_y.

increasing over time if its initial value exceeds the infinite stream of marginal non-timber benefits (i.e. $\mu_0 - \frac{a_f}{r} > 0$)[3].

In many poor countries where gold is mined, the royalty tax that is presently charged could be designed to take care of the damage. Since this tax is positively related to marginal damages, it will create the incentive for damage reduction. So far many poor but gold-rich countries that have FDI in gold mining have kept the severance tax very low and constant, and basically for the wrong objective of getting some revenue for losing the extracted gold.

Proposition 2:

The optimal tax should increase (decrease) when adjusted net return on all other assets in the economy is higher (lower) than the growth in the price of gold.

The preceding proposition addresses the behavior of the tax rate over time. Taking the logarithm of the tax equation (i.e. $\theta = \frac{\mu}{\alpha p}$), we have

$$\log(\theta(t)) = \log(\mu(t)) - \log(p(t)) - \log(\alpha) \tag{15}$$

The time derivative of equation (15) gives the growth equation of the tax rate as

$$\frac{\dot{\theta}}{\theta} = \frac{\dot{\mu}}{\mu} - \frac{\dot{p}}{p} = r - \frac{a_f}{\mu} - \frac{\dot{p}}{p} \tag{16}$$

The term $\frac{\dot{\mu}}{\mu}$ of equation (16) denotes adjusted net return on all the other assets in the economy (i.e. $r - \frac{a_f}{\mu}$) from equation (9). Thus, the tax rate will increase if the ratio of

[3] From equation (14), $\frac{\partial \mu(t)}{\partial t} = r\left(\mu_0 - \frac{a_f}{r}\right)e^{rt} > 0$ if $\mu_0 - \frac{a_f}{r} > 0$ or $\mu_0 > \frac{a_f}{r}$.

the marginal non-timber forest benefits from the remaining forest stock to the scarcity value of the remaining forest stock decreases, given the return on all other assets in the economy and the growth in the exogenous price of gold. As the rate of deforestation increases, the ratio decreases, and given r and $\frac{\dot{p}}{p}$, the tax rate will increase. Moreover, with the growing commercialization of the enormous non-marketed ecological services that tropical forests provide, such as insurance and information value of biodiversity, amenity values, watershed protection, carbon storage and sequestration and option values, the scarcity value of tropical forest is increasing (Pearce, 2001).

1.5 Comparative Static Analyses of the Severance Tax

In this section, we investigate the comparative static analyses of the tax rate with respect to the price of gold and the discount rate. Within the 15-year period of 1987-2001, the highest cumulative average price of gold declined from US$446 in 1987 to the lowest of US$271 in 2001 with overall average of US$354.5 and a high standard deviation of 54.9. It will therefore interest the social planer to determine how the optimal tax rate should respond to price volatility.

Furthermore, discount rates in most poor countries are generally low and also volatile. In Ghana, nominal discount rates had been low and unstable even after the IMF sponsored economic recovery program. Within the period between 1987 and 2001, the lowest discount rate of 20% was recorded for 1991 and the highest of 45% was recorded for 1995-1997, with a mean and standard deviation of 32% and 8.1 respectively. Due to the high rate of inflation within this period, real interest rates were generally very low and more volatile.

Proposition 3:

The tax is negatively related to the price of gold (p) and positively related to benefit discount rate (r) if $\mu_0 - \frac{a_f}{r} > 0$.

To determine the comparative static analysis of θ with respect to p, equation (13) is used to obtain the following equation.

$$\frac{\partial\theta}{\partial p} = -\frac{\mu}{\alpha p^2} < 0 \tag{17}$$

The result from the analysis indicates that the firm should have increased share in per unit price of the resource if the price of the resource increases. The intuition behind the former is that price increment does not stem from increased damage to the rainforest and must therefore benefit the firm. The social planer should therefore charge lower royalty tax rate if the exogenous price of gold increases. Thus, the firm should receive increased after tax per unit price of the resource if the price of the resource increases, given that the increment does not increase the optimal extraction path of the resource.

The relationship between the share and the rate of time preference is not obvious. There are two effects of the increased social rate of time preference: it reduces the firm's share due to the faster growth of the initial user cost of the forest stock, but increases due to a reduction in the infinite discounted value of the marginal damage to the forest. The comparative static analysis of θ with respect to r is[4]

$$\frac{\partial\theta}{\partial r} = \frac{1}{\alpha p}\frac{\partial\mu(t)}{\partial r} = \frac{1}{\alpha p}\left(\left(\mu_0 - \frac{a_f}{r}\right)te^{rt} + \left(e^{rt}-1\right)\frac{a_f}{r^2}\right) > 0 \tag{18}$$

[4] Equation (18) is positive because the optimal path of the shadow price of the forest is assumed to be non-decreasing (i.e. $\mu_0 > \frac{a_f}{r}$).

Higher discount rates generally indicate scarcity of the resources, hence the optimal path of the shadow price of the resource increases and consequently the path of the tax also increases.

1.6 Numerical Simulation

In this section, we present numerical illustration of some key results of our model. Due to lack of adequate data on mining activities in Ghana, we calibrated data for $y(t)$ and also used some specific functional forms of $c(y)$ and $a(f)$. It is important that the results from the simulations are interpreted with extreme caution because of the nature of the data used. Emphasis should be on the direction and the relative rather than the absolute values of the estimates. Since the size of the mining industry was stable before the mineral sector liberalization policy in 1986 (Akabzaa and Darimani, 2001), we hypothesise that the data on gold production between 1960 and 1985 describes the slope of the extraction path for 30 years beginning 2002 since there has been very low increments in investment since 1998 (Ismi, 2003). Moreover, the 30 years corresponds to the maximum number of years that concessions are usually exhausted in Ghana (Hilson, 2004). To obtain the slopes, the following OLS regression estimates were obtained from the data:

$$y(t) = y_0 - \underset{(5.46664)}{11.17855t} - \underset{(0.196520)}{0.5809315t^2} \tag{19}$$

$\bar{R}^2 = 0.9443$; F(2, 23) = 212.92; **T**=26

Where the standard errors are in parentheses, t is the time trend for the period of 1960 to 1985, and the coefficients of t and t^2 are significant at 5% and 1% respectively. Using the last available data on gold production (i.e. 2,023,000 ounces in 2002) as the baseline for y_0 and the estimated coefficients of t and t^2, we generated data for $y(t)$ shown in Figure 2A.

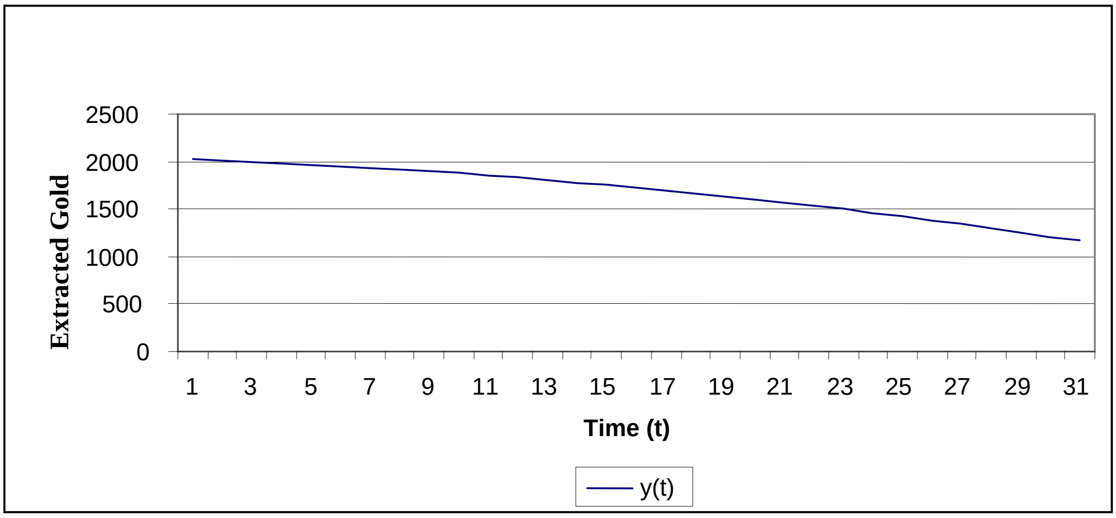

Figure 2A: The Time Path of Gold Extraction.

Secondly, a total of 37 million ounces of gold exists within a 50km radius (i.e. $7857.14\,km^2$) (Mines News Feature Story, 2005). From this, gold yield per acre of deforested land (i.e. α) is 19.06 ounces, which is used for the simulation. Furthermore, statistics available indicates that Ghana's remaining forest stock as at 2000 was 15,653,800 acres and annual deforestation is 65,000 acres (FAO, 2003). This puts the forest stock as at 2002 (i.e. f_0) at about 15,523,800 acres. Using the discrete time representations of the forest stock dynamic equation (i.e. $f_t = f_{t-1} - \frac{1}{\alpha} y_t$), gold stock dynamic equation (i.e. $x_t = x_{t-1} - y_t$) and the data generated for $y(t)$, we generated the time series data for the forest and gold stocks. Figure 2B shows the time path of the remaining forest stock, if mining is the only activity that leads to deforestation.

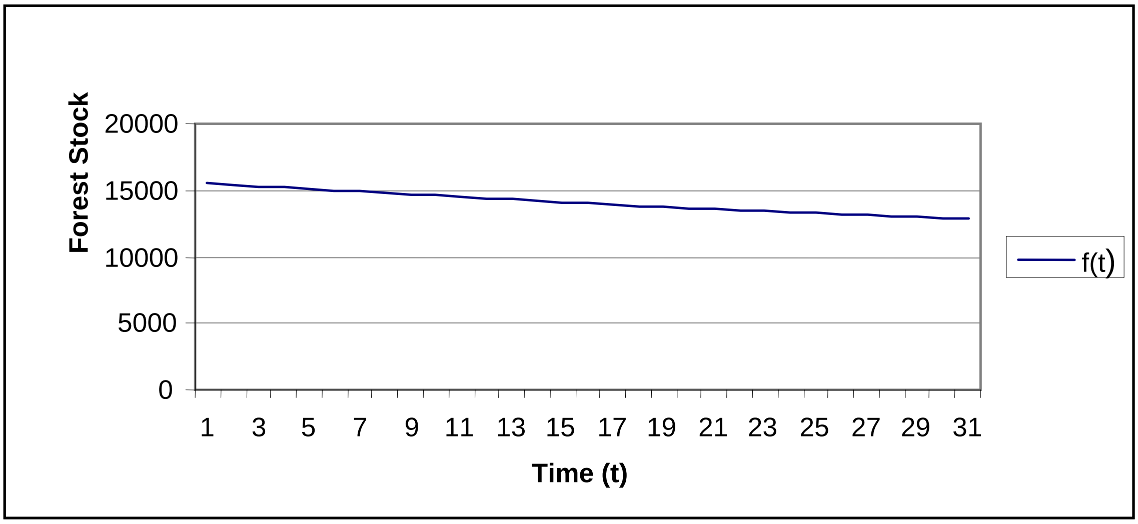

Figure 2B: The Time Path of Remaining Forest Stock.

From equations (9) and (13) $\theta = \frac{\left(\mu_0 e^{rt} + \left(1 - e^{rt}\right) a_f / r\right)}{\alpha p}$. A rough estimate for a_f is from benefit transfer from earlier studies in some developing countries. The estimate of genetic resources plus forest product collection and environmental benefits from an acre of tropical rainforest per annum is about \$170.15. This is made up of estimated potential annual genetic resource value of US\$8.51 per acre in Western Ecuador (Simpson et al., 1996) plus annual sustainable non-timber forest product harvest value of US\$162 per acre in Cambodia (Bann, 1997). We used the 15-year (1987-2001) average price of gold (i.e. \$354.50) for p. Furthermore, to select a value for μ_0, we rely on the restrictions that the scarcity value of the forest should be increasing overtime (i.e. $a_f / r < \mu_0$). Since $a_f / r \approx 3403$, values of $\mu_0 = \{3405, 3905, 4405\}$ were chosen for the simulation. Finally, since information on cost of mining is difficult to obtain, we used the specific functional form of the cost function in Fraser (1999) and chose some values for the parameters in the function. The parameter values were carefully chosen so that the average costs, which is \$258.00, for the 30-year simulation period is the same as the forecast for 2005 for a mining firm in Ghana (Russell and Associates, 2004). The cost function is

$$c(y) = \kappa + \gamma y^2 \tag{20}$$

Where $\kappa, \gamma > 0$; so that $c_y > 0$; and $c_{yy} > 0$. For the purpose of the simulation, the following parameter values were chosen: $k = 200000$ and $\gamma = 0.01$. Due to the high volatility of the domestic real interest rate we used the U.S. government 20-year treasury bills rate of 5% (i.e. $r = 0.05$) such that $e^{-rt} \approx \rho(t) = \left(\frac{1}{1-r}\right)^t = 0.952381^t$.

The results obtained from the simulations for the dynamic tax rate, which should be interpreted within the context of the parameter values chosen are shown in Figures 3A through C. From the figures, higher initial values of the scarcity value of the forest (i.e. μ_0), induce higher optimal path of the tax, which may result in a decrease in the terminal period of the gold extraction. Moreover, for each of the three chosen values of μ_0, the dynamic tax rate increases overtime with a minimum value of about 50% for all $\mu_0 > \frac{a_f}{r} = 3403$. This implies that the current tax of 3% that is charged is too low.

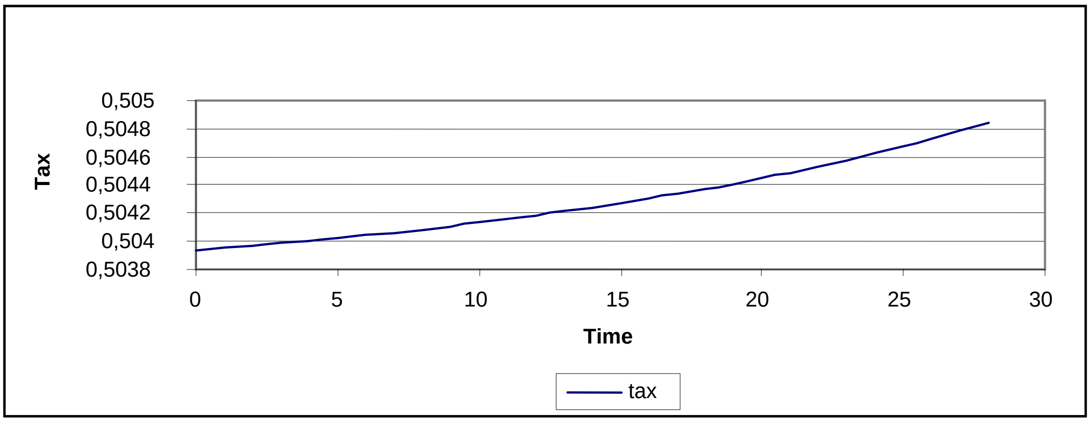

Figure 3A: The Time Path of the Tax if $\mu_0 = 3405$. The corresponding T=29.

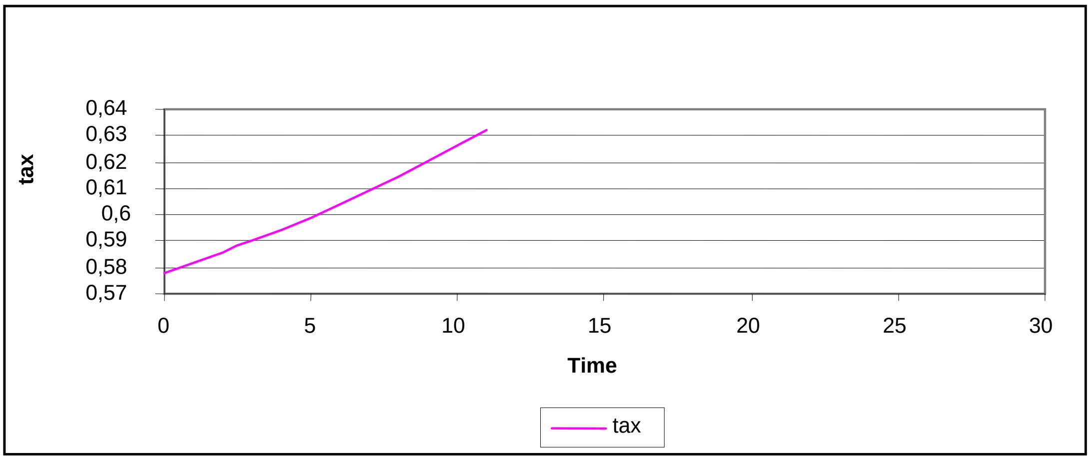

Figure 3B: The Time Path of the Tax if $\mu_0 = 3905$. The corresponding T=12.

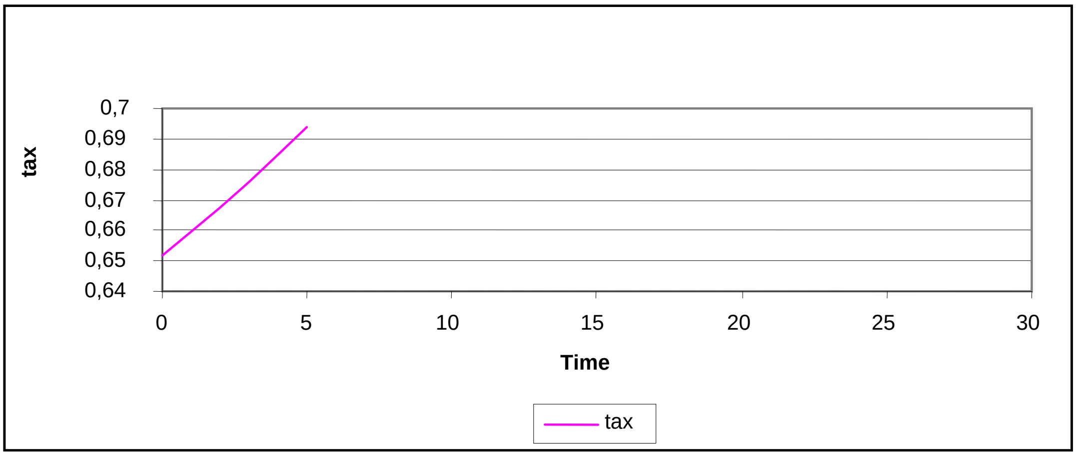

Figure 3C: The Time Path of the Tax if $\mu_0 = 4405$. The corresponding T=6.

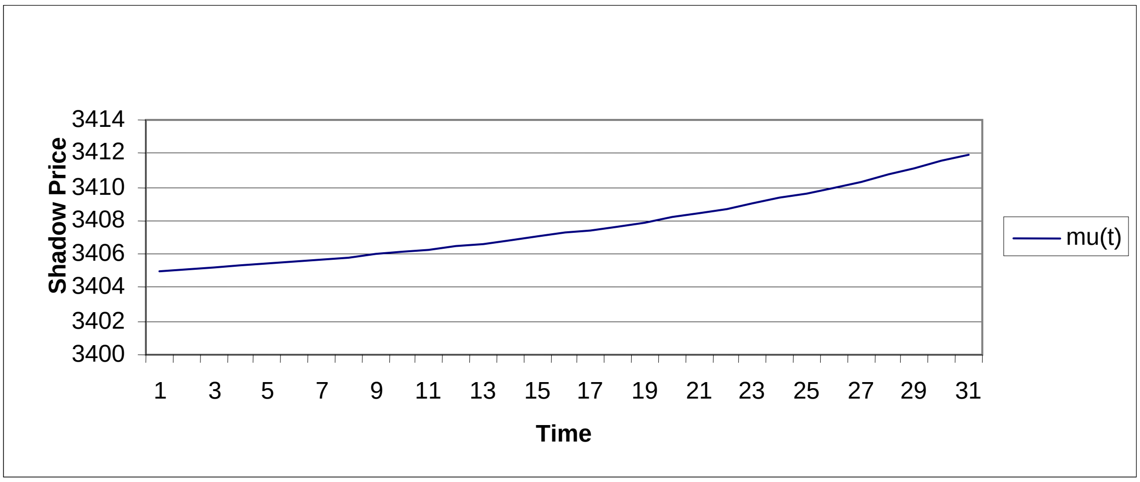

Figure 4: Time Path of the Shadow Price of the Rainforest (i.e. $\mu(t)$) for $\mu_0 = 3405$.

The optimal path relationship between the sum of present value (PV) of social benefit or surplus and the initial value of the shadow price of the forest is shown in Figure 4. The social benefit includes the tax revenue from mining and the stream of non-timber benefits from the remaining forest stock. Clearly, higher optimal path of the tax will lead to higher forest conservation but this may not necessarily generate higher stream of social benefits. From Figure 5, the highest social benefit results from the path with the lowest gradient. However, if the rate of increase of the tax path is very low, say for $\mu_0 = 3404$, the stream of benefits to the resource-rich country may be low compared to what is associated with $\mu_0 = 3405$.

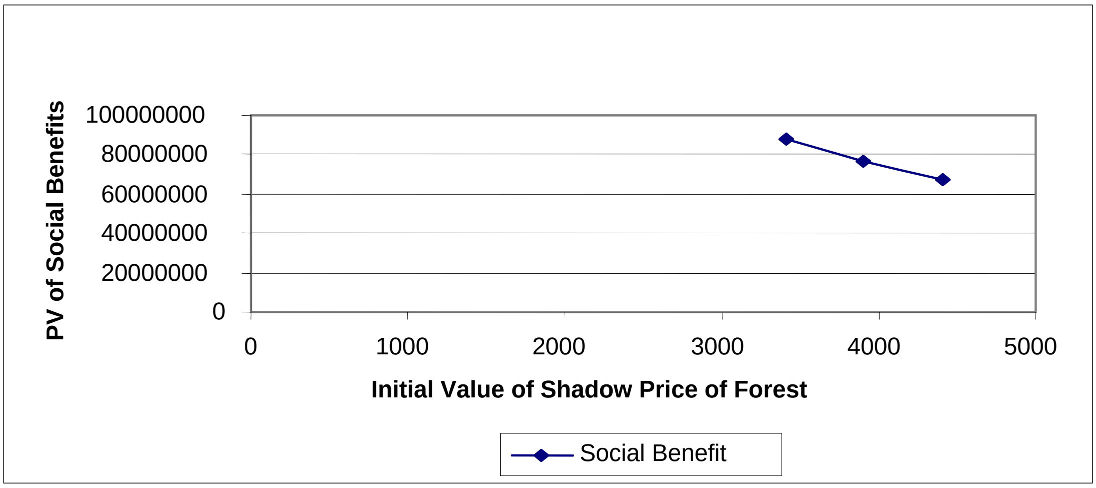

Figure 5: The Optimal Path Relationship Between μ_0 and the Present Value of Social Benefits.

1.7 Conclusion

The destruction of rainforests for the purpose of mining gold in Ghana is a common problem that many other tropical countries face. Any attempt at ignoring the environmental opportunity costs of extraction when selecting a tax rate may lead to irreversible loss of forest ecosystems.

By examining gold extraction by foreign companies in rainforest in Ghana, we have shown that the ad valorem severance tax on gross revenue from production, which is currently charged, can be used to internalize environmental opportunity cost if it equals the ratio of marginal damage of gold extraction to the marginal benefit from the sale of gold. The tax is dynamic because it is a function of the growing scarcity value of the remaining rainforest stock. Comparative static analyses of the tax with respect to the exogenous price of gold and discount rate show that the tax is positively related to benefit discount rate and negatively related to exogenous price of gold. Furthermore, the growth of the tax rate is equivalent to the net return on all other assets in the economy and the growth rate of the price of gold. Moreover, empirical results indicate that the 3 percent tax that is currently charged is too low to fully represent the external cost of extraction (i.e. lost forest benefits). Lack of data to estimate the cost and marginal non-timber forest benefits, however, limits the reliance on the absolute values of the estimates from the simulations. Further research on estimating these functions will be useful.

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1.9 Appendix

Simulated Data

P	**354,5**		
a_f	**170,15**		
α	**19,06**	**170,15**	Biodiversity plus Non-timber Benefits (USD per acre), p.1:24
r	**0,05**	**354,5**	Average Gold Price (USD per ounce), 1987-2001, p. 1:24
ρ	**0,952381**	**19,06**	Gold Density (ounces per acre), p. 1:23
$f(0)$	**15523,8**		
N	**1**		
K	**200000**		
V	**0,35**	**15523,8**	Estimated Forest Remaining (1000 acres), 2002
γ	**0,01**		
μ_0	**3405**		

Simulated Data (Continued)

t	y(t)	x(t)	f(t)	R(t)	θ*R(t)	a[f(t)]	c(t)
0	2022,73	295883,6	15523,8	717057,9	361247	2641375	240914
1	2010,971	293860,9	15417,68	712889,2	359153	2623318	240440
2	1998,049	291849,9	15312,17	708308,5	356851	2605365	239922
3	1983,966	289851,9	15207,34	703316	354341	2587529	239361
4	1968,721	287867,9	15103,25	697911,7	351624	2569818	238759
5	1952,314	285899,2	14999,96	692095,4	348701	2552243	238115
6	1934,745	283946,9	14897,53	685867,3	345569	2534814	237432
7	1916,015	282012,1	14796,02	679227,3	342231	2517543	236711
8	1896,122	280096,1	14695,49	672175,4	338685	2500438	235953
9	1875,068	278200	14596,01	664711,6	334932	2483511	235159
10	1852,852	276324,9	14497,64	656835,9	330971	2466773	234331
11	1829,474	274472,1	14400,42	648548,4	326803	2450232	233470
12	1804,934	272642,6	14304,44	639849	322428	2433900	232578
13	1779,232	270837,7	14209,74	630737,7	317845	2417787	231657
14	1752,368	269058,4	14116,39	621214,5	313055	2401904	230708
15	1724,342	267306,1	14024,45	611279,4	308058	2386261	229734
16	1695,155	265581,7	13933,98	600932,5	302853	2370867	228736
17	1664,806	263886,6	13845,05	590173,6	297441	2355735	227716
18	1633,295	262221,8	13757,7	579002,9	291822	2340873	226677
19	1600,622	260588,5	13672,01	567420,4	285994	2326292	225620
20	1566,787	258987,8	13588,03	555425,9	279960	2312003	224548
21	1531,79	257421,1	13505,83	543019,5	273718	2298016	223464
22	1495,631	255889,3	13425,46	530201,3	267268	2284342	222369
23	1458,311	254393,6	13346,99	516971,2	260611	2270990	221267
24	1419,829	252935,3	13270,48	503329,2	253746	2257972	220159
25	1380,184	251515,5	13195,99	489275,4	246673	2245297	219049
26	1339,378	250135,3	13123,57	474809,6	239392	2232976	217939
27	1297,41	248795,9	13053,3	459932	231904	2221019	216833
28	1254,281	247498,5	12985,23	444642,5	224208	2209437	215732
29	1209,989	246244,2	12919,43	428941,1	216304	2198240	214641
30	1164,535	245034,3	12855,94	412827,8	208192	2187439	213561

Simulated Data (Continued)

R(t)	[(1- θ)]*R(t)	π (t)	a()+ θ R(t)	PV(t) of Social Benefit	$\mu(t)$	θ
717058	355811	114896	3002622	3002622	3404	0,503791
712889	353737	113297	2982470	2840448	3404	0,503799
708309	351458	111536	2962216	2686817	3404	0,503807
703316	348975	109614	2941870	2541298	3404	0,503815
697912	346287	107529	2921442	2403478	3404	0,503824
692095	343395	105280	2900943	2272965	3404	0,503833
685867	340298	102866	2880384	2149387	3404	0,503843
679227	336997	100285	2859773	2032388	3404	0,503853
672175	333491	97538	2839123	1921630	3404	0,503864
664712	329780	94621	2818443	1816794	3405	0,503875
656836	325865	91534	2797744	1717572	3405	0,503887
648548	321745	88275	2777035	1623675	3405	0,5039
639849	317421	84843	2756328	1534827	3405	0,503913
630738	312892	81236	2735633	1450765	3405	0,503927
621214	308159	77451	2714960	1371239	3405	0,503941
611279	303221	73488	2694319	1296013	3405	0,503956
600932	298079	69344	2673721	1224862	3405	0,503972
590174	292732	65017	2653176	1157572	3405	0,503989
579003	287181	60505	2632694	1093939	3405	0,504007
567420	281426	55806	2612287	1033770	3406	0,504026
555426	275466	50918	2591963	976884	3406	0,504045
543020	269302	45838	2571734	923104	3406	0,504066
530201	262933	40564	2551610	872268	3406	0,504088
516971	256361	35094	2531601	824217	3406	0,50411
503329	249584	29425	2511718	778803	3406	0,504134
489275	242602	23553	2491970	735886	3406	0,50416
474810	235417	17478	2472368	695331	3407	0,504186
459932	228028	11195	2452923	657011	3407	0,504214
444642	220435	4702	2433645	620807	3407	0,504243
428941	212637	-2003	2198240	534054	3407	0,504274
412828	204636	-8925	2198240	508623	3407	0,504306

Note: π (t) is profit of the firm and ***R(t)*** is total Revenue at time ***t***

Paper 2

Dynamic Model of Regulatory Compliance in Fisheries: The Case of Mesh Size

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Abstract

This paper employs a dynamic model for crimes that involve time and punishment to analyze the use of nets with illegal mesh size under two management regimes: competitive and regulated open access fishery. The model is based on the consideration that the illegal net is used repeatedly until detection; the net decreases the expected weight recruitment of catchable fish; and lowers the average cost of harvest. We find that under the competitive fishery, the equilibrium stock and harvest are lower if the fishers use the illegal mesh size. However, under regulated open access, the size of the equilibrium stock depends on the ratio of the elasticity of catchability coefficient to the elasticity of the hazard rate. Furthermore, under some condition, the fine for violation should be higher under open access relative to the competitive fishery for any given level of violation.

Keywords: Crime; Dynamic Model; Fishery; Regulation.

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2.1 Introduction

The use of illegal fishing technology has played a major role in fish stock depletion in many developing coastal countries where monitoring and enforcement of fishery regulations are far from being complete. The illegal technology generates technological externality, which may include reduction in the stock available to other fishers and an opportunity cost of a larger and more valuable fish in the future. A typical example of such destructive technology is the use of illegal mesh size, which has characterized all types of fisheries in developing coastal countries. According to FAO (2001), the use of illegal nets, which are highly destructive, is popular in many African countries and is widely used along the coasts, in lagoons, estuaries and rivers. This situation is not different from what prevails in other continents. It has been noted that, for example in a fishery in India, some fishers use stake nets with mesh sizes of less than 5mm in contiguous row to filter young prawns, whiles the prescribed minimum is 35mm (Srinivasa, 2005).

Following the seminal paper by Becker (1968), considerable amount of theoretical and empirical research has been done on violation of fishing regulations. For the theoretical researches see, e.g., Sutinen and Anderson (1985), Anderson and Lee (1986), Charles et al. (1999), Hatcher (2005), and Chavez and Salgado (2005); and the empirical works include Furlong (1991), Hatcher et al. (2000), and Hatcher and Gordon (2005). Consistent with Becker's configuration, fisheries economists have considered fishing regulations such as closed area and quantity restriction, for which an illegal fisher is a rational self-interested economic agent who maximizes a one-period expected utility. Consequently, he engages in the illegal fishing if the expected gain from violation outweighs the gain from legal fishing and to the extent that the expected marginal gain equates the expected fine for violating the regulation. Notably, fishery crimes that involve the use of fishing nets with illegal mesh sizes are committed repeatedly, especially in developing countries where fishers use one net, until it is detected and punished. Thus, the rational fisher who acquires the illegal net weighs the stream of economic benefits from fishing with the illegal mesh size and the expected fine, which is in the future. This type of crime may, therefore, be modeled as a dynamic problem.

This paper contributes to the theoretical literature on economics of fishery crimes by extending the existing static expected utility model to a dynamic model that includes time and punishment. The paper combines the features of a dynamic model of crime (Davis, 1988) that involves the use of nets with illegal mesh size (Boyd, 1966; Turvey, 1964) and a bioeconomic fishery model (Clark, 1990).

Whilst the use of a net with illegal mesh size may enable more fish to be caught at a lower per unit cost of harvest, it reduces the expected weight of fish that is recruited to the catchable fish stock (Boyd, 1966; Escapa and Prellezo, 2003)[1]. Thus, by reducing the mesh size some fishes that were too small to be caught become catchable. Based on these facts, we characterize optimal fish stock, harvest, and fine under two management regimes: competitive fishery and regulated open access fishery. The paper shows that under the competitive fishery, the equilibrium fish stock and Nash equilibrium harvest are lower if the fishers use the illegal mesh size relative to a situation where none use it. However, under regulated open access regime, the size of the equilibrium stock depends on the ratio of elasticity of catchability coefficient to elasticity of the hazard rate. Furthermore, the fine should be higher under open access relative to the competitive fishery for any given level of harvest and mesh size if the shadow value of stock externality from a marginal decrease in the mesh size is less than the marginal shadow value of the corresponding risk.

The rest of the paper is organized as follows: In the next section (2.2), the model for competitive operated fishery is presented, followed by a regulated open access fishery in section 2.3. The conclusion of the paper is presented in the last section (2.4).

[1] This specification is in contrast with Armstrong and Clark (1997); and Garza-Gil (1998), which assumed that different technologies impact harvest but not the growth function.

2.2 The Model

2.2.1 The Competitive Fishery and Illegal Mesh Size

Consider a fishery operated by N competing fishers so that a fish caught by one fisher imposes some technological externality, and N is not large enough to induce open access which completely dissipates the resource rent. Following Boyd, and Armstrong (1999), we use a simplified version of the cohort model of Beverton-Holt (1957) and age-structured models of fishery biologists by letting the set of all the fish within the management area be categorized as either having reached the catchable size, which we shall refer to as fish stock (x); or immature fish[2]. Note that as the mesh size becomes smaller, some fishes from the immature category join the fish stock (i.e. x). Thus, the categorization depends on the mesh size. Furthermore, let recruitment refer to the number or biomass (weight) of fish that joins the fish stock from those that have not yet reached the catchable size per each time period. Since illegal mesh size catches illegal size fish, the illegal mesh size reduces the weight recruitment of each fish. If we assume that natural mortality is a function of age; and the number of eggs laid is determined by the size of the fish stock, then we can specify the weight recruitment function as

$$r = n(x)\omega(\alpha, x)\,, \qquad (1)$$

where r is the weight recruitment (function) into the fish stock; n is number of eggs hatching per year, which is assumed to be a function of fish stock; ω is the expected weight of a typical fish at age of recruitment, which is a function of the mesh sizes used by the N fishers and fish stock; and $\alpha = \left(\alpha_1(t), \alpha_2(t), \ldots \alpha_N(t)\right)$ is inversely related to the mesh size in inches for fisher 1 to N, so that $r = r(\alpha, x)$.

[2] Moreover, we assume a tropical fishery with pelagic species such as mackerel, anchovy, sardines, etc, which have relatively short periods of maturation. These stocks do not fit well into the age structured model.

If constant returns to scale is assumed between fishing capacity (i.e. all the inputs used in fishing) and effort ($E(t)$), then the harvest or production function of each fisher $i = 1, 2..., N$ is

$$h_i = f(x, E_i, \alpha_i)\,. \tag{2}$$

For tractability, a simple Schaefer harvest function is assumed so that $h_i = f(x, E_i, \alpha_i) = a(\alpha_i).E_i.x$, where $a(\alpha_i)$ is catchability coefficient function[3]. The fish stock evolution or dynamics will be increasing in the size of the recruited stock but decreasing in total harvest. Thus,

$$\dot{x} = w(r(\alpha, x), x, h) = \Lambda(x, \alpha) - \sum_{i=1}^{N} h_i\ , \tag{3}$$

where $\dot{x} \equiv \dfrac{dx}{dt}$ and $\Lambda(x, \alpha)$ is adjusted natural growth function. The gross revenue that each of the N fishers obtain from fishing is qh_i, where q is fixed price per kilogram of harvest. Let the unit cost of harvest for each fisher be

$$c(x, \alpha_i) = \frac{c}{a(\alpha_i)x}\,, \tag{4}$$

where c is a constant per unit cost of effort and $c(x, \alpha_i)h_i = c(E) = cE$, following Boyd.

As noted earlier, many fisheries in developing countries are characterized by the use of nets with illegal mesh sizes. As could be inferred from equations (1), (2) and (4), we consider a situation where the illegal fishing net has the advantage of reducing the unit cost of harvest but negatively affect the weight recruitment of the stock. It is assumed that if a fisher is caught for using the illegal net, he pays a fixed fine F. Following the dynamic deterrence model of Davis, Nash (1991) and Leung (1991, 1994) we assume

[3] As noted by Mackinson et al. (1997), changes in fishing technology impact on catchability coefficient.

that each violator does not know the exact time of detection but only some probability distribution of the time of detection denoted $g(t) \equiv \frac{dG(t)}{dt}$, which is the continuous time analogue of the probability in a one-period expected utility model of Becker. Where $G(t)$ is the cumulative density function (cdf), which defines the probability that detection would have occurred at time t in the future. The survivor function is therefore, $(1-G)$. Furthermore, without loss of generality, we assume that each violator, if caught, will not be allowed to fish anymore and will have zero exogenous income for the rest of the planning horizon. It is the case that illegal nets are seized when detected and we assume that the user will lose his fishing license or will be barred from fishing. This harsh punishment reduces the propensity to recidivate (Smith and Gartin, 1989). Thus, a fisher obtains the profit of $\left(q-c(x,\alpha)\right)h_i$ from using the illegal net until the act is detected at time t. He pays an expected present value of a fine of $\int_0^\infty Fg(t)\,\mathrm{e}^{-\delta t}\,dt$ when he is caught and gets nothing for the rest of the planning horizon. Furthermore, since fishing nets are usually bequeathed to subsequent generations, we assume that each fisher has an infinite planning horizon. The future benefits and costs are discounted at a discount rate of δ.

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 $p(\alpha_i,\bar{\mathrm{M}}) = \frac{g}{(1-G)}$, where $\bar{\mathrm{M}}$ is some exogenous fixed enforcement effort of the management authorities which can be normalized or set to one (i.e. $\bar{\mathrm{M}}=1$), $p_{\alpha_i} > 0$ and $p_{\alpha_i\alpha_i} \geq 0$[4]. The assumption that the hazard rate, which is formed subjectively, depends on the illegal mesh size stems from the fact that the size composition of catch of a fisher could signal his use of illegal mesh size. The expected present value of the fine can be rewritten as $\int_0^\infty Fp(\alpha_i)(1-G)e^{-\delta t}dt$. For simplicity, if it is

[4] The specification of the (expected) probability as a function of violation level in a fishery and enforcement effort is consistent with Hatcher (2005).

assumed that all the fishers are homogenous, the objective of a violating fisher, who uses a net with illegal mesh size, is to

$$\max_{\substack{\alpha \\ h}} \quad V = \int_0^\infty \left\{ \left(\left(q_i - c(x,\alpha) \right) h_i - p(\alpha_i) F \right) (1-G) \right\} e^{-\delta t} dt \quad , \qquad (5)$$

s. t.

$$g = p(\alpha_i)(1-G) , \qquad (6)$$

$$\dot{x} = \Lambda(x,\alpha) - \sum_{i=1}^{N} h_i , \qquad (7)$$

with $x \geq 0$, $x(0) = x_0$, $\alpha_i(0) = \alpha_{i0}$, $\Lambda_x > 0$, $\Lambda_{xx} < 0$, $\Lambda_{\alpha i} < 0$, $\Lambda_{\alpha i \alpha i} \geq 0$.

Where V is the value function; and Λ_z and Λ_{zz} are the first and second order derivatives of $\Lambda(\bullet)$ with respect to z. The constraints to equation (5) are the hazard rate (i.e. equation 6), which is an equation of motion; and the fish stock evolution equation (i.e. equation 7). From the specification of the hazard rate function, it is assumed that the instantaneous conditional probability of a vessel being detected is independent of whether the other fisher uses the illegal net or not. As noted earlier, the values of α is inversely related to the mesh size[5]. Moreover, each fisher is assumed to have full information about the type of net used by the other. This dynamics continues until a violator is caught, hence the right hand side of the value function is multiplied by the survivor function.

The current value Hamiltonian associated with equations (5) through (7) for each fisher is equation (8). Following Johnston and Sutinen (1996), the shadow value of the fish

[5] In the coastal countries of West Africa, for example, there is evidence of illegal use of decreasing mesh size over the years from the minimum legal size of 25mm to about 5mm (Yeboah, 2002). Consequently, it is reasonable to assume that α is a flow variable.

stock, $\mu_i(t)$, is multiplied by the survivor function (i.e. $\mu_i(t)(1-G)$). Note that $\lambda_i(t)$ is the shadow cost of the cumulative density function defining the time of detection or simply the shadow cost of taking the risk.

$$H = \left(\left(q - c(x,\alpha)\right) h_i - p(\alpha_i)F + \lambda_i p(\alpha_i) + \mu_i \left(\Lambda(x,\alpha) - \sum_{i=1}^{N} h_i \right) \right)(1-G). \tag{8}$$

The maximum principle for the two flow variables, h and α for fisher i, gives equations (9) and (10) respectively.

$$\begin{aligned} & q - c(x,\alpha) \begin{pmatrix} > \\ < \end{pmatrix} \mu_i \quad \Rightarrow \\ & h_i = h_{i\max} \quad \text{if} \quad x_i > x_i^{**} \\ & h_i = 0 \qquad \text{if} \quad x_i < x_i^{**} \end{aligned} \tag{9}$$

$$\frac{\partial H}{\partial \alpha_i} = 0 \qquad h_{i\alpha}\left(q - \mu_i\right) = p_{\alpha_i}\left(F - \lambda_i\right) - \mu_i \Lambda_{\alpha_i}. \tag{10}$$

Where x_i^{**} is the equilibrium stock under competitive fishery. Equation (9) defines inter-temporal profit maximizing level of harvest. In order to maximize profit, the fisher will choose a level of harvest that equates his marginal profit, (i.e. $q - c(x,\alpha)$) to the adjusted shadow value of the fish stock (i.e. μ). However, since harvest is not an argument in the maximum principle (i.e. Equation 9), a singular solution is not trivial. If $q - c(x,\alpha_i) > \mu_i$, then the existing stock exceeds what is optimally desired hence harvest will be at its maximum (i.e. $h_i = h_{i\max}$). On the other hand, if $q - c(x,\alpha_i) < \mu_i$, then the existing stock is lower than what is optimally desired, hence the fisher will not harvest any fish at all (i.e. $h_i = 0$) until the stock recovers. For the purpose of our analyses, we assume for tractability but without loss of generality, that an interior solution exits (i.e. $x_i = x_i^*$, $q - c(x,\alpha_i) = \mu_i$ and $h_i^* = \left(0, h_{i\max}\right)$).

Equation (10) defines inter-temporal profit maximizing illegal mesh size. Thus, the fisher will choose the mesh size that equates expected net marginal benefit from violation (i.e. $h_{i\alpha}\left(q-\mu_i\right)$), to the marginal cost, which is the difference between an adjusted fine and the shadow value of the growth of the stock (i.e. $p_{\alpha_i}\left(F-\lambda_i\right)-\mu_i\Lambda_{\alpha_i}$). The equation can be re-specified as

$$F = \frac{h_{i\alpha}q + \mu_i\left(\Lambda_{\alpha_i} - h_{i\alpha}\right)}{p_{\alpha_i}} + \lambda_i . \tag{10′}$$

Following Leung, and Hatcher, it is assumed that society derives benefit from the (illegal) harvest, which is $\left(q - c(x,\alpha_i)\right)h_i$, and incurs a social cost of violation which is a function of the quantity of the illegal harvest, $m(\alpha)$. Consistent with the competitive harvesting of the resource, the social planner will optimize the net social benefit from violation, subject to the dynamic equation of the stock (i.e. equation 3)[6]. From the maximum principle, the marginal social damage is $m_{\alpha_i} = h_{i\alpha}q + \mu_i\left(\Lambda_{\alpha_i} - h_{i\alpha}\right)$, which is the numerator of the first term of equation (10′). Consequently, the fine necessary to internalize the technological externality should be set at

$$F^* = \frac{m_{\alpha_i}}{p_{\alpha_i}} + \lambda_i . \tag{10′′}$$

[6] The Hamiltonian for the problem is $H = \left(q - c(x,\alpha_i)\right)h_i - m(\alpha) + \mu_i\left(\Lambda(x,\alpha) - \sum_{i=1}^{N} h_i\right)$.

PROPOSITION 1. *The equilibrium level of stock is time dependent if each fisher fishes with the net with illegal mesh size and constant if each does not. Moreover, if illegal mesh size is used, the equilibrium fish stock and harvest are much lower than if it is not used.*

Proof. The proof of the preceding proposition requires deriving and comparing the harvest levels under the two situations. The costate equation associated with the fish stock from the Hamiltonian (i.e. equation 8) is $\dot{\mu}-\left(\delta+p(\alpha_i^v)\right)\mu=-\frac{\partial H}{\partial x}\frac{1}{1-G}$[7]. At the equilibrium stock level we have $\dot{x}=0$ and $\dot{\mu}_i=0$. Assuming symmetric appropriation, we have the following expression for the equilibrium stock that is derived from the costate equation, and equations 7 and 9.

$$\delta=\left(\Lambda_x\left(x^{**},\alpha^{\mathrm{v}}\right)-\Lambda\left(x^{**},\alpha^{\mathrm{v}}\right)\frac{c_x(x^{**},\alpha_i^v)}{N\left(q-c(x^{**},\alpha_i^v)\right)}\right)-p(\alpha_i^v), \tag{11}$$

where x^{**} is the equilibrium level of stock if the fishers violate the regulation. Note that from equation (11), it is assumed that the N fishers have identical illegal nets, α^{v}. The Nash equilibrium harvest for each fisher is $h_i^{**}=\frac{\Lambda(x^{**},\alpha^{\mathrm{v}})}{N}$. If the fishers do not violate the regulation, we have $\Lambda\left(x^{*},\alpha^{\mathrm{L}}\right)>\Lambda\left(x^{**},\alpha^{\mathrm{v}}\right)$, where α^{L} is the legal minimum mesh size, and the corresponding steady state interior solutions for the fish stock is computed from

$$\delta=\left(\Lambda_x\left(x^{*},\alpha^{\mathrm{L}}\right)-\Lambda\left(x^{*},\alpha^{\mathrm{L}}\right)\frac{c_x(x^{*},\alpha_i^L)}{N\left(q-c(x^{*},\alpha_i^L)\right)}\right), \tag{12}$$

---

[7] Note that, from the Hamiltonian, $\frac{d}{dt}\left(\mu(1-G)\right)=\dot{\mu}(1-G)-\mu g$.

The corresponding steady state harvest is $h_i^* = \frac{\Lambda(x^*, \alpha^L)}{N}$. Since the survivor function is time dependent, it follows that x^{**} and, consequently, $h^{**} = Nh_i^{**}$ are also functions of time. From equation (11), we know that $c_x < 0$. Furthermore, the last term in the bracket of equation (11) is less than that of equation (12) (i.e. $\frac{c_x(x^{**}, \alpha_i^v)}{q - c(x^{**}, \alpha_i^v)} < \frac{c_x(x^*, \alpha_i^L)}{q - c(x^*, \alpha_i^L)}$). This is because $\frac{c_x(x^{**}, \alpha_i^v)}{c(x^{**}, \alpha_i^v)} = \frac{c_x(x^*, \alpha_i^L)}{c(x^*, \alpha_i^L)}$ and $q - c(x^{**}, \alpha_i^v) > 0$. Also, without violation, the growth of the stock is higher than what will prevail with violation, and $\Lambda_x\left(x^*, \alpha^L\right) > \Lambda_x\left(x^{**}, \alpha^v\right)$, hence $x^{**} << x^*$.■

Note that if a sole owner operates the fishery, the optimum level of stock, which will coincide with that of the social planner, will be higher than the Nash equilibrium level of stock for the competitive fishery. Thus, the level of stock desired by the social planner can be computed from

$$\delta = \left(\Lambda_x\left(x^*, \alpha^L\right) - \Lambda\left(x^*, \alpha^L\right) \frac{c_x(x^*, \alpha_i^L)}{\left(q - c(x^*, \alpha_i^L)\right)} \right) \qquad (12')$$

The implication is that, competition for the resource leads to a reduction in the equilibrium stock.

2.3 Regulated Open Access Fishery

As clearly noted in the fishery literature, open access fisheries dissipate potential profits due to free entry and exit of vessels in the industry (Gordon, 1954; Lueck, 1998). The competition for the stock by very large users leaves the resource with no shadow value and the industry commits a level of capacity that equates profits to zero. According to Edwards et al. (2004), a fish stock does not have any capitalized value in an open access or regulated open access since it is prohibitively expensive for individuals to exclude others and conserve the asset for future use. Due to the restriction on the mesh size of the fishing nets in the fishery, we refer to this type of open access as a regulated open access. The potential violator of the fishing regulation will maximize his value function (i.e. equation 13) with respect to the intensity of violation[8]. The corresponding first order condition of the problem is equation (14).

$$V_i = \left(qh_i - c(x,\alpha_i)h_i - p_i F_o\right)(1-G)\,. \tag{13}$$

$$\frac{\partial V_i}{\partial \alpha_i} = 0: \qquad p_\alpha F_o = qh_{\alpha_i}\,. \tag{14}$$

Note that if $p_i F_o$ is replaced by $m_o(\alpha)$ in the social planner's problem, the marginal benefit from violation, qh_{α_i}, will be equal to the marginal social cost, $m_{o\alpha_i}$. Hence, under the regulated open access, $F_o^* = \dfrac{m_{o\alpha_i}}{p_{\alpha_i}}$.

In open access equilibrium, if symmetry is assumed, the following condition also holds for each fisher:

$$qh_0 - c(x_0,\alpha_i)h_0 - p_i(\alpha_i)F_o = 0\,, \tag{15}$$

where h_0 and x_o are open access levels of harvest and stock respectively. Using $c(.)h(.) = c.E_0$, where E_o is open access level of effort, and combining equations 14 and 15, we get

$$x_0 = \frac{c}{qa(\alpha_i)} + \frac{p(\alpha_i)F_o}{qE_0 a(\alpha_i)}\,. \tag{16}$$

---

[8] Since the fishery is characterized by free entry and exit, if the probability of getting away with the crime at any point in time is $1-b_i$, following the standard model of Becker, the expected utility function is $E(u_i) = \left(qh_i - c(x,\alpha)h\right)\left(1-b_i\right) + \left(qh_i - c(x,\alpha)h_i - F_o\right)b_i = qh_i - c(x,\alpha)h_i - b_i F_o$. Moreover, since the fisher will not be allowed to fish anymore after the act is detected, expected utility is multiplied by the survivor function and the result is the value function (i.e. equation 13).

PROPOSITION 2. *In a regulated open access fishery, the equilibrium level of stock will be lower if fishers violate the fishing regulation than otherwise, if the ratio of elasticity of the hazard rate to the elasticity of catchability coefficient of violation is greater than one; and the ratio is less than* $1-a/a(\alpha_i)$.

Proof. By substituting qh_{α_i} for the expected fine and rewriting the second term of equation (16) in terms of elasticity, we have

$$x_o = \frac{c}{a(\alpha_i)q} + \frac{\alpha_i h_\alpha}{a(\alpha_i)E_0\eta_\alpha}, \tag{17}$$

where $\eta_\alpha = \dfrac{\alpha_i p_\alpha}{p(\alpha_i)}$ is the elasticity of hazard rate. But $h_\alpha = a(\alpha_i).E_0.x_0$, hence

$$x_o = \frac{c}{a(\alpha_i)q}\bigg/\left(1-\frac{\varepsilon_\alpha}{\eta_\alpha}\right), \tag{18}$$

where $\varepsilon_\alpha = \dfrac{\alpha_i a_\alpha}{a(\alpha_i)}$ is the elasticity of catchability coefficient. From the above equation, it follows that the necessary condition for existence of equilibrium stock is $\varepsilon_\alpha < \eta_\alpha$. Thus, a percentage increase in intensity of violation should lead to a greater percentage increase in the instantaneous conditional probability than in the catchability coefficient. Moreover, the perfect compliance open access stock is $x_{oo} = \dfrac{c}{aq}$, where $a = a(\alpha_i^L)$. This implies that if fishing is done with the illegal mesh size, the regulated open access stock will be higher than what prevails in the absence of fishing illegally if $x_0 < x_{00} = \dfrac{c}{aq}$. Thus

$$x_o < x_{oo} \Rightarrow \frac{c}{a(\alpha_i)q}\bigg/\left(1-\frac{\varepsilon_\alpha}{\eta_\alpha}\right) < \frac{c}{aq}. \tag{19}$$

After some rearrangements we have

$$\frac{\varepsilon_\alpha}{\eta_\alpha} < 1 - \frac{a}{a(\alpha_i)}. \blacksquare$$

PROPOSITION 3. *The fine (i.e. F) for using a net with illegal mesh size in a regulated open access fishery, must be higher than the fine in a competitive fishery for the same illegal net and harvest, if* $\mu_i\left(\Lambda_{\alpha_i} - h_{i\alpha}\right) < -\lambda_i p_{i\alpha}$.

Proof. From equations (15) and (10′) we have $\underset{o}{F^*} = \frac{m_{o\alpha}}{p_\alpha}$ and $F^* = \frac{m_{i\alpha}}{p_\alpha} + \lambda_i$ respectively, where the shadow value of cumulative probability defining the time of detection (i.e. λ) is negative[9]. It follows by comparing the two equations that $\underset{o}{F^*} > F^*$ for any given values of α and h_i, if $\mu_i\left(\Lambda_{\alpha_i} - h_{i\alpha}\right) < -\lambda_i p_{i\alpha}$. Where $\mu_i\left(\Lambda_{\alpha_i} - h_{i\alpha}\right)$ is the shadow value of stock externality and $-\lambda_i p_{i\alpha}$ is the marginal shadow value of increased risk associated with marginal decrease in the mesh size. ■

[9] Note that from the Hamiltonian, we have $\dot{\lambda} - \delta\lambda = -\frac{\partial H}{\partial G} = \frac{H}{1-G}$. However, it is intuitively unrealistic to justify exogenous growth in the shadow value of the cumulative probability or the cost of taking the risk of fishing with the illegal mesh size (i.e. $\dot{\lambda}_i \neq 0$), hence $\lambda = -\frac{H}{\delta(1-G)} < 0$. Consequently, the condition can be restated as $\mu_i\left(\Lambda_{\alpha_i} - h_{i\alpha}\right) < \frac{p_{i\alpha} H}{\delta(1-G)}$.

2.4 Conclusion

This paper contributes to the existing theoretical literature by extending a one-period expected utility model to a dynamic one to accommodate a repeated fishery crime, which is a chronic problem in many (developing) countries. It incorporates time and punishment to analyze the continuous use of fishing net with illegal mesh size under competitive, and regulated open access fishery management regimes, where regulatory enforcement is incomplete.

It has been shown that, under competitive fishery, the equilibrium fish stock and harvest are much lower if each fisher fishes with the illegal mesh size relative to the situation where he does not. However, under regulated open access regime, the size of the equilibrium stock depends on the ratio of the elasticity of catchability coefficient of the mesh size to the elasticity of the hazard rate. The policy implication from the analysis is that the fine should be higher in open access relative to competitive fishery for any given level of harvest and mesh size if the shadow value of stock externality from a marginal decrease in the mesh size is less than the marginal shadow value of the corresponding risk.

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Paper 3

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

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3.1 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; 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 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, as well as perceived legitimacy, fairness of the regulation increase the intensity of violation, and younger skippers have higher intensity of violation. Moreover, skippers who were aware that 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 3.2 followed by the survey design and data description in section 3.3. In section 3.4, we present and discuss the estimation of our model and the final section, i.e. section 3.5, has the conclusion of the paper.

3.2 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; 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 $d^i_y>0, d^i_{yy}\leq 0$, $z^i_x>0$, and $z^i_{xx}\leq 0$. 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 $g(t)\equiv\dfrac{dG(t)}{dt}$, 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 patch of the net with small mesh size is 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

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

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

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

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[1], then

[1] 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.

$(1-G(t)) = e^{-p(y_i)t}$, $G(t) = 1-e^{-p(y_i)t}$ 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.

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

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[2]

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

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

[2] Note that equation (6) can be re-specified as $V^{i1}(y) = \left[(1-G)d^i(y_i) - gq_iF\right]_i / \left(\delta_i + p(y_i)\right)(1-G)$ 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.

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.

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

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

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

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

Note that if risk neutrality is assumed, the term at the right hand side of equation 7 denotes expected (indirect) utility from illegal harvest. Following Furlong (1991) and Hatcher et al. (2000), B_i, which is utility shift vector across fishers, includes psychological and socioeconomic characteristics of the skipper such as age and wealth of the fisher, 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; 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).

3.3 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, each for a boat, constituting approximately 41% of the total number of boats within the district, 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[3]. 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. The target species include sardine, grunt, ilisha, threadfin, and mackerel.

[3] 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).

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[4]. 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[5]. Only 3 (0.010%) respondents refused to

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

[5] 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.

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[6]. The mean value of the catch of juvenile fishes[7] 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 about $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[8]. 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*.

[6] The proportion of violators within the sample is very high because, since we were interested in the intensity of violation, and not violators and non-violators, we drew the random sample from a stratified sample of skippers (boats) that were likely to use the illegal mesh nets. We inferred this from information on the type of net used by a boat, which were collected from fishermen within the community.
[7] When fishermen land their catch, juvenile fishes are sorted and sold separately so it is easy to collect the data on the disaggregated catch.
[8] 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). The time frame for the conditional probability of detection is one year.

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%[9]. 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[10].

[9] 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.

[10] 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.

3.4 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[11]. 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.

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 to obtain total fine, and the expected fine is the product of the total fine and the probability of being fined, given an arrest. The expected logarithm of fine is the product of the probability of being fined given an arrest and the logarithm of total fine.

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.

[11] 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.

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 (Continuous)	1.31	0.71
Age of Skipper (Continuous)	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* (5-1:strongly agree-strongly disagree)	1.81	1.08
Dummy for Regulation *Protects Stock* (5-1:strongly agree-strongly disagree)	1.65	1.06
Dummy for Regulation is *Fair* (5-1:strongly agree-strongly disagree)	2.35	1.17
Dummy for Regulation is a *Right Thing* (5-1:strongly agree-strongly disagree)	1.76	1.02

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

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 et al. (2003), the variables were logged to transform them towards normality before they were used in the regression.

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 (coefficients) 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))[12]. 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 rejected the hypothesis that the probabilities were endogenous[13].

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 (0.059)***	-0.228 (0.058)***
Instantaneous Conditional Probability of Arrest given Detection	-0.193 (0.056)***	-0.201 (0.056)***
Expected Log of Total Fine	-0.051 (0.026)**	-0.051 (0.026)**
Individual Discount Rate	0.100 (0.040)**	0.093 (0.040)**
Log (Age of Skipper)	-0.255 (0.096)**	-0.264 (0.096)***
Log (Wealth of Skipper)	0.003 (0.027)	0.005 (0.027)
Dummy for *Ownership* (=1 if skipper owned; 0 otherwise)	0.075 (0.055)	0.072 (0.055)
Dummy for E*xogenous Factors Leading to Declining Stock*	-0.112 (0.057)*	-0.109 (0.057)*
Dummy for *Social Pressure*	0.333 (0.121)***	0.313 (0.120)***
Dummy for *Regulation Protects Well-being*	-0.046 (0.036)	-0.066 (0.030)**
Dummy for *Regulation Protects Stock*	0.017 (0.043)	
Dummy for *Regulation is a Right Thing*	-0.066 (0.044)	
Dummy for *Regulation is Fair*	-0.034 (0.028)	-0.047 (0.027)*
Constant	1.711 (0.417)***	1.741 (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%.*

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

13 It must be noted that since the probabilities have values of zero and one, the square and the square root of these values are the same as the original values. Consequently, the only explanatory variable in the estimated equation for the Glejser's test is the probability, but not the square and square root of the probability, which reduces the reliability of the test.

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, reported in Table 3, are 0.138 and 0.129 in the first equation, and 0.122 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 0.138% and 0.122% 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 0.129% 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 with respect to 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%[14]. 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 of 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[15]. 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

[14] 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.

[15] 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.

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	0.138	0.129	0.610
Probability of Arrest Given Detection	0.122	0.128	0.635
Expected Log of 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	0.494
Dummy for Fairness of Regulation		0.111	2.345
Dummy for Well-being		0.120	1.810

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 the declining stock had, on the average, higher intensity of violation with elasticity coefficient that is about the same as that of the 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.

3.5 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. 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.

3.6 References

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Paper 4

Does Ostracism Decrease Over-fishing? A Common Pool Resource Experiment in Ghana

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Abstract

This paper investigates how the presence of ostracism, which is a familiar punishment mechanism to the subjects in an experiment, affects harvest in a common pool resource experiment. The experiment was framed as a fishing problem and the subjects were young fishers in Ghana. We find that the introduction of the possibility to ostracize other members of a group at a cost to the remaining members of the group decreased over-fishing significantly in comparison to the case where ostracism was not possible. Moreover, the subjects demonstrated a strong desire to ostracize those who over-fished.

Keywords: Common Pool Resource; Experiment; Ostracism.

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4.1 Introduction

A community-owned fishery is an example of a common pool resource problem, which is characterized by rivalry in fishing and difficulties in excluding any potential fisher. Unmanaged fisheries are prone to over exploitation, a situation referred to as “the tragedy of the commons” in Hardin (1968). Several ways to overcome this problem have been discussed in the literature. For example, Dietz et al. (2003) discussed restriction of access, which according to Hardin (1968) could either be by privatizing the common pool resource or keeping it as a public property but restricting the right to entry, and/or creation of incentives to mitigate overuse of the resource.

This paper reports results from a common pool resource experiment among young fishers, i.e. the next generation fishers, in Anyako, a village located in the Volta Region of Ghana.[1] In particular, we study ostracism, which is an existing punishment mechanism against those who may use inappropriate technologies to over-fish. Rules and social norms have impact on our behavior and attitude, and as argued by Bowles (1998), markets and other economic institutions influence the evolution of our values and tastes. However, the threat of social sanctions such as ostracism may make it rational, from the cost-benefit viewpoint, to abide by norm-guided behavior (Jon, 1989). The objective of this paper is to investigate if the presence of this type of institution or rule affects individuals’ behavior.

In Ghana, due to limited budget of government, the state institutions that are responsible for governing common pool resources are generally weak, and as a consequence, fishing regulations have been decentralized to the communities.[2] A chief fisherman oversees all

[1] Murphy and Cardenas (2004) present an excellent introduction on how to conduct a common pool resource experiment. Furthermore, some examples of experiments with subjects who face social dilemmas in resource extraction in their daily lives include Cardenas (2003); Carpenter and Seki (2005); and Gaspart and Seki (2003). There are several studies that compare student with non-student subjects. For example, Cardenas and Carpenter (2004) find small differences between students and non-students in common pool resource experiments. Other studies that compare the two groups of subjects in public good experiment include Carpenter et al. (2004); Carpenter and Seki (2005); Gächter and Herrmann (2005); and List (2004).

[2] In 1997, the fishery sector supported over 1.5 million people in Ghana, which constituted about 8.3% of the total population (Atta-Mills et al., 2004).

fishing activities within a fishing community[3], and this gives him the power to implement traditional fishing laws, resolve fishing related conflicts and punish violators of traditional fishing laws. His decisions are made in consultation with his counsel of elders, which usually consists of the heads of each clan within the community. Once the chief fisherman takes a decision, it is binding on all fishers within his community.[4] The fishing laws, which operate at community level, do not differ much across communities. For example, they include prohibition of fishing on off-fishing days, which is usually one day in a week, and the use of destructive fishing techniques and equipment such as dynamites, cyanide and DDT (Overå, 2001). The punishment for not obeying the laws, which is decided by the chief fisherman, ranges from oral disapproval to life-time ostracism depending on which law is violated. For example, whilst using child labor during school hours may receive oral disapproval, fishing with poisons could receive ostracism as a punishment. Ostracism is employed either as a direct sanction when some traditional fishing laws are not obeyed or when a fisherman fails to pay a fine imposed on him. There are, however, some differences regarding the structure of punishment across communities[5].

Common pool resource experiments in a laboratory setting, without any form of formal or informal institutions, or communication among the members, have generally found over-harvesting at a level close to the Nash equilibrium (e.g. Walker et al., 1990; Cardenas, 2003; Casari and Plott, 2003). One way to mitigate the problem of overuse of the resources is to allow for communication. For example Cardenas (2003) and Ostrom (1999) found that non-binding face-to-face communication resulted in a significant

[3] The position of a chief of a community is hereditary, but the chief fisherman, who is usually the most skillful fisherman, is elected. Traditionally, he occupies the position until his death.

[4] In October 1995, the Fishery Department established a new bond of partnership with the local fishing communities through a Community Based Fisheries Management Program (CBFM), which is a part of the Fishery Sub-sector Capacity Building Program (FSCBP) that was funded by the World Bank to improve long-term sustainable management of fisheries in Ghana (Bannette et al, 2001). Committees were formed within each community, which normally consisted of the chief fisherman, and representatives of fishermen, fish processors, fishmongers, and fishing gear owners, with the responsibility of drafting fishing laws, and to assign appropriate sanctions. This document was then submitted to the District Assemblies for approval. This process merely legitimized the traditional laws and did not conflict with the traditional institutions (Bannette et al, 2001).

[5] Ostracism as a punishment mechanism exists in all rural communities in Ghana and is always applied as the last resort when any social norm, e.g. stealing, fighting, adultery, etc., is violated. This punishment is so severe that if an ostracized individual is not reaccepted into the community it is better for him to relocate to a distant community.

reduction in the over-use of the common pool resource.[6] Recent experiments on common pool resources and public goods have focused on the effect of allowing different methods of punishment among members in a group. Ostrom et al. (1992) and Cardenas et al. (2000) found that cooperation and average earnings increase if monetary sanctioning is available in a common pool resource experiment. Similarly, monetary punishment in a public good experiment introduced by Fehr and Gächter (2000), resulted in a significant increase in the contribution to a public good, although it was costly to punish another member.[7] [8] Few experiments have applied ostracism using students as subjects. Soest and Vyrastekova (2004) in a common pool resource experiment, and Masclet (2003) in a public good experiment included two stages in each period, where members were ostracized from a second stage activity in that period only. In the former, it was a gift-exchange game and was another public good experiment in the latter. Contrary to theoretical predictions, Soest and Vyrastekova (2004) found that members selectively excluded free riders from the gift giving. Masclet (2003) examined the effect of costly and costless ostracism (which was enforceable if at least one member voted for ostracism) on cooperation in a linear public good game. He found that the possibility of exclusion from the second public good experiment increased average contributions to the first public good. However, it should be noted that in the two papers, the ostracism applies in a second activity during the same period, while in this paper we assume ostracism applies to the single activity, i.e. the fishery. Closely related to our approach is the work by Cinyabuguma et al. (2005) which introduced ostracism, based on majority voting, in a public good experiment. A cost was imposed on those who voted for ostracism, if and only if the subject that they voted against was ostracized. The ostracized members were then assigned to play another

[6] The positive effect of communication has also been found in public good experiments (e.g. Isaac and Walker, 1988; and Sally, 1995).

[7] Similar results have been found in other public good experiments on students (e.g. Ostrom et al., 1992; and Bochet et al., 2006). Gächter et al. (2004) find that some definitions of trust have a significant impact on contribution in a public good experiment in Russia. Carpenter et al. (2004) had similar findings in their experiments in Vietnam and Thailand.

[8] Other institutions include e.g. introduction of the possibility of communicating disapproval in a public good experiment as a form of non-monetary punishment (see Masclet et al., 2003). The results of Masclet et al. (2003), for example, indicated a higher level of contribution to the public good after its introduction, but the positive effect on cooperation from the possibility of non-monetary punishment declined overtime in their experiment. In a common pool experiment, Ostrom et al. (1992) found that by allowing face to face communication within groups, average net yield increased compared to the baseline situation where no communication was allowed.

public good experiment and a lump sum cost was imposed on members who voted to ostracize a member given that the member they voted against was excluded in that period. Their results show an almost maximal level of contribution to the public good among the non-excluded members.[9] [10] [11]

We conducted the experiment among young artisanal fishers in Anyako, a community in the Volta Region of Ghana, where fishing is the main occupation of the people, including high school students who engage in fishing activities after school hours and on holidays. We only selected students engaged in fishing for the experiment, and on average the students engaged in fishing related activities for 12.5 days per month. Thus, our sample consists of next generation of potential full-time fishers who were very much aware of the problems in the fishery as well as ostracism as an institution. Our experiment shows that without the possibility to ostracize, over-fishing is substantial, and hence they are not influenced by current institutions in the experiment. When ostracism was introduced, subjects were ostracized although it was costly for the remaining members to ostracize a member. Moreover, as a result of the introduction of ostracism, there was a sharp decline in over-fishing compared to a baseline treatment in which it was not possible to ostracize. The results from our experiment can be viewed in the light of the fact that, in the absence of external sanctions, internalized norms may not be sufficient in regulating resource appropriation. Consequently, for example, a fishing licensing system with decentralized monitoring which makes it possible to withdraw the license upon violation might be a feasible policy tool to regulate over-fishing.

The rest of the paper is organized as follows: In the next section, we introduce our specific experimental design, and the organization of the experiment is in section 4.3.

[9] Interestingly, the effects on net earnings are positive and significant, which is uncommon in public goods experiments with monetary punishment. Masclet (2003); and Soest and Vyrastekova (2004) conducted an experiment with a one-period ostracism from a second activity in that period. In the former case, a public good experiment was followed by a second public good experiment in each period, while in the latter a common pool resource experiment was followed by a gift exchange.

[10] Baland and Platteau (2000) noted that ostracism will result in cooperation, i.e. adopting the social optimum strategy, if the voting is based on a majority rule and if the decision to ostracize is irrevocable. Similar argument is found in Hirshleifer and Rasmusen (1989) where a prisoner's dilemma game was solved recursively.

[11] Cardenas et al. (2000) found that when people get used to imperfect monitoring they rapidly move towards self-interested choices.

The results of the experiment are presented in section 4.4, and section 4.5 concludes the paper.

4.2 Experimental Design

In our experiment, each group consists of 8 members and the total endowment of time for labor activities in a period is set to 8, which is framed as 8 months in a year to mimic the maximum number of months a fisher could fish within a year.[12] Member *i* can allocate the total time available to his/her to fishing, which is denoted x_i, and other activities, which correspond to $8 - x_i$. We assume that there is no alternative work option for the fishers and this resembles the common situation in most fishing villages in Ghana.[13] Following the literature on common pool resource, we assume that the aggregated production function is "hump-shaped" (e.g. Dasgupta and Heal, 1974; Ostrom et al., 1992; and Fischer et al., 2002, and this is specified as a two-piece linear production function). The pay-off of the group is presented in equation (1)

$$F(x) = 100 * \begin{cases} 0.26x & 0 \le x \le 24 \\ 11.1 - 0.2x & 24 \le x \le 64 \end{cases} \tag{1}$$

The pay-off to member *i* does not only depend on how many months he/she has been fishing, but also the total amount of months that the other group members have been fishing.

$$f_i(x_i, x_{-i}) = 100 * \begin{cases} 0.26x_i & 0 \le x \le 24 \\ 11.1\left(\dfrac{x_i}{x}\right) - 0.2x_i & 24 \le x \le 64 \end{cases} \tag{2}$$

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[12] In all fishing communities in Ghana, fishing is strictly prohibited one day per week. The day varies across communities. Moreover, fishing does not normally take place on Sundays since most fishers go to church; mend their nets or attend social gatherings such as funerals and marriage ceremonies. Thus, on average a fisher goes fishing about five days in a week and this approximately adds up to 8 months in a year, as in our experiment.

[13] In contrary, Cardenas et al. (2002) and Cardenas (2003) allow for an outside option in their common pool resource experiments.

The aggregated social optimum level is 24 months, which corresponds to a social optimal level of 3 months per year for each member since they are symmetric. Without any social sanction, the self-interested fisher will do what is best for him by fishing for more months than the social optimal number of months. Based on equation (2), we constructed the payoff matrix that was handed out to the subjects in the experiment. In the pay-off matrix, the columns indicate the number of months fished by a given member, while the rows show the total number of months fished by the rest of the members. For all possible combinations the earnings from fishing for member *i* can be read. The exchange rate used for the payment in the experiment was 35 Cedis for 1 experimental currency unit.[14] If each member spends the social optimum amount of time of 3 months, the payoff for each equals to 624 Cedis.

The common pool resource experiment is run for 30 periods and we use two different treatments in the experiment, following a similar set up in Cardenas et al. (2000). In both treatments, the first 15 periods consisted of an ordinary common pool resource experiment after which there was a break. After the break the experiment continued for another 15 periods, and this was known at the beginning of the experiment. Half of the sample continued with the ordinary common pool resource experiment, while ostracism was introduced in the other half. Theoretically, for any common pool resource problem with large number of potential users, if a member of the group is ostracized, average earnings for the aggregate social optimum number of months will increase for the remaining members of the group. However, in real life fishery, members in a group interact in many ways that enhance mutual benefits. For example, fishermen in Ghana collectively help each other to retrieve lost or entangled nets at sea, haul the fishing boats, carry and dry fishing nets after landing and serve as watchdogs in protecting fishing equipment from theft, which are activities that benefits from a larger group. Thus ostracizing a member will have a negative effect on the remaining group members in the mentioned contexts. The size of these effects may however vary across the

[14] 35 Cedis is the Ghanaian currency equivalent to US$0.036 at the time of the experiment. From personal enquiry at the time of the experiment, the average earning of a fisher within Anyako (the area where the experiment was conducted) is about 70,000 Cedis (7.87 USD) per day and the length of a fishing day is on average 6 hours. This was higher than the average earning of 40,233.30 Cedis (4.50 USD) in the experiment. However, the hourly wages are approximately the same between fishing and taking part in the experiment. These levels had been set based on a pilot experiment in May 2004.

fishers, but we assume in our experiment that these effects, which are expressed as costs, are the same across all the remaining members in the group. To account for this loss, a cost was introduced in the experiment. Moreover, the cost is set such that irrespective of the number of months a fisher fishes, it would always be costly to ostracize a member. The cost was calculated by comparing the payoff between two different situations. In one situation, all fishers except one fished for the social optimal number of months while the deviating fisher fished for the maximum possible months. This was compared to another situation where the deviating member had been ostracized, and the group only consisted of members fishing at the social optimal level. For example, if all but one member fished at the social optimal number of months, i.e. 3 months, while the remaining subject fishes for 8 months, the payoff to each member fishing 3 months is 54.1. In the situation with 7 subjects, i.e. in a situation where the deviating member has been ostracized, the payoff is 78 each. The difference between the two payoffs is 24, and to make exclusion costly to the remaining members, we added a cost of 3 to make the cost equal to 27, which implies that the net payoff to each of the remaining subjects is 51 (i.e. 78-27).[15] If a cost is imposed on the remaining members, member *i*'s return presented in equation (2) would then be modified to

$$g_i(x_i, x_{-i}) = 100 * \begin{cases} 0.26x_i - \Omega_j & 0 \le x \le 24 \\ 11.1\left(\dfrac{x_i}{x}\right) - 0.2x_i - \Omega_j & 24 \le x \le 64 \end{cases} \tag{3}$$

where Ω_j is the cost of having j members ostracized. Thus, the catch rate per se is not affected, but losses occur for other reasons as discussed above, and this result in a lower net return. In our experiment, each member had the opportunity to vote to ostracize another member from his/her group at the end of each period. Based on majority voting, it was decided whether a member was life-time ostracized. In such a case, that member would not earn any money in the subsequent periods of the experiment. This mimics the fact that if a fisher is ostracized from a community, he no longer gets any income from

[15] Similarly, if the group consists of 7 subjects and a subject is ostracized, the remaining 6 subjects will get an average payoff of 104 if each invests the social optimal level of effort of, in this case, 4 months. To make the exclusion costly, we added 3 to the difference between 104 and 51, thus making the cost of exclusion equal to 56. Following the same procedure, 3 was added to the cost if an additional individual is excluded.

the fishing activity and may also find it difficult to secure an alternative viable economic activity. The number of votes required to ostracize a member and the cost of ostracism imposed on the remaining members are presented in Table 1 in Appendix I.

4.3 Organization of the Experiment

The experiment was conducted in Anyako, a fishing community in the Volta region of Ghana. The Volta region is one of ten administrative regions of Ghana and it is located in the south-east part of the country, sharing borders with Togo.[16] In Anyako, fishing activities are intense, and the area is rich in fresh water fishes, such as tilapia, but there are indications that many of the species in the region are over fished (Butler, 1995). Anyako is located in the Keta Lagoon basin in the southern part of the Volta region, where occupation possibilities, except occupations related to fishing, are very limited. Normally, the men in fishing communities in Ghana are involved directly in fishing and maintenance of the boats, and fishing equipment, while the women prepare and sell the catch (Walker, 2002). Although it is generally a taboo for women to go fishing in many fishing communities in Ghana, some of them are indirectly involved in fishing by owning fishing boats and nets, which are operated by men on a share contract basis. Thus, after the variable cost of the fishing expedition is deducted, a proportion of the revenue from the catch, usually a half, goes to the crew and the other half to the owner of the fishing gear. Moreover, some women also give loans to male fishers in order to support their fishing activities.

In the experiment, we targeted those individuals who are teenagers or young adults and are currently involved in fishing activities. Our sample is from students at the Anyako Secondary School, which is the highest institution for formal education within the area, and is attended by teenagers and young adults from the area. A week before the experiment, a pre-experimental questionnaire was administered to 168 of the first to third year Senior Secondary School students who volunteered to take part in answering the questions. This constituted of slightly less than 70% of the 244 students enrolled at

[16] It is named after the Volta River, which is one of the largest man-made lakes in the world.

the school. All the students had been informed a week before we conducted the pre-experimental questionnaire about this event at a general meeting. One of the purposes of the pre-experimental questionnaire was to identify the sample for the common pool resource experiment, which should only consist of individuals who were currently involved in fishing activities. The respondents were asked a set of background questions, mainly relating to personal characteristics and fishing experience. At the end, the subjects were also asked whether they would be willing to participate in an "economic choice decision", which was to take place a week later. Each subject was given two versions of the questionnaire, one in Ewe[17] and one in English. The questionnaire was developed in English and later translated to Ewe by one translator and another translator conducted the reversed translation. Afterwards the translators met and discussed any differences that have occurred, and agreed on the final wordings. From the 168 subjects who answered the pre-experimental questionnaire, we randomly selected 128 subjects with fishing experiences. We conducted the experiment on a weekday to reduce the potential problem of individuals not showing up. Moreover, in order to encourage the subjects to turn up, we asked the headmaster to announce the names that had been selected to participate at a gathering of all the students of the school.

On the day of the common pool resource experiment, the identities of the randomly selected subjects were checked against the list of names, and each subject was then given a numbered card outside the room. These numbers assigned them to a pre-marked seat. The numbered cards were also used to assign the subjects to the two treatments (i.e. the baseline and ostracism treatments). Each treatment consisted of eight groups. The venue for the experiment was two halls, one for each treatment groups. The subjects took their seats at numbered, but otherwise empty, desks with enough space between the desks to guarantee privacy when making their decisions. They were informed that they were about to make "economic choice decisions", and that the amount that each subject would earn would depend on their own decisions as well as on the decisions made by the other subjects in their group. They then received the instructions of the game and the payoff matrix (see Appendix II). Moreover, each

[17] Ewe is the first language in Anyako. It is one of the nine government-sponsored languages in Ghana and spoken by 13% of the Ghanaian population.

subject was given 30 experimental cards, i.e. one card per period, to be handed to the instructor indicating how many months they fished during a specific period, or year as framed in the experiment. All 30 experimental cards were delivered before the experiment began to avoid a re-start effect[18] in period 16, i.e. the break motivated for resting and where we also introduced ostracism treatment in half of the groups. Finally, the subjects were given one record sheet on which they recorded the number of months that all the other members of their group fished. This information was written down on a sheet of paper and handed out by an instructor to each member of a group after each round. This approach was chosen to avoid any effect from different degree of recall on behavior. The subjects were then given some time to read the instructions, and thereafter the instructor read the instructions aloud, first in English and then in Ewe to all the subjects. The subjects then answered six exercises in a language of their choice to test their understanding of the pay-off matrix. The correct solutions, as well as how to obtain them from the pay-off matrix, were explained orally and also written down on the chalk board. Half of the sample, i.e. 64 subjects, sat in each of the two halls.

In the experiment, we used partner matching but a subject remained anonymous to other members in his/her group. In our case, it is natural to let the subjects remain in the same group to replicate living in a community. The procedure during one period in the experiment was as follows; the subjects first decided on how many months to spend on fishing, which was written down on the experimental card for that specific period. This card was then collected by one of the instructors. The contributions and earnings were computed manually, and then written down on a sheet of paper and handed out to the various members of each group, but no additional information was provided. After the fifteenth period, there was a break, which had been announced before the experiment, giving the subjects the possibility to rest and to introduce the ostracism in half of the group. It was stated in the instructions that they were not allowed to talk to each other during the experiment, which also applied during the break, and the instructors were spread out during the break to ensure that the subjects obeyed this rule. In the ostracism treatment, the subjects were given information about the rules of ostracism at the end of the break. They were informed that they had the opportunity to vote a member of their

[18] Re-start effect has been found in public goods experiments (e.g. Andreoni, 1988).

group out. In order to be able to conduct voting, each subject was given 15 voting cards. Each subject had the opportunity to vote after the information on the total and individual months of fishing was handed out to him or her. The information was provided in the same way as in the non-ostracism treatment during the first 15 periods, and in the baseline treatment after period 15. The voting cards were then collected by one of the instructors, and if refrained from voting an "X" was written down on the card. Each member was then given a written feedback on the number of votes he/she received in that period after which the experiment continued to the next period. If an individual received the minimum number of votes required for ostracism or more, he/she was informed by an instructor orally to leave the room.[19] It was stressed that anyone could refrain from voting if he/she desired to do so. If a subject was voted out, he/she would not continue to take part in the experiment and thus would not have the possibility to earn any money from the subsequent periods of the experiment. The decision to ostracize an individual was based on majority voting as presented in Table 1. In total, the experiment lasted for 5 hours, consisting of the first two hours for the ordinary CPR, and then a 15 minute break, and finally two hours and forty five minutes for the treated section.

All subjects were paid the following day. Their earnings were calculated and the amounts were put in an envelope, which was sealed and the subject's identification number was written on it. The envelopes were then spread on a table in an empty classroom to be picked up by the subjects. Each subject entered the room through one door and left through another door. When the subject entered the room, he/she showed his/her numbered identification card from the experiment the day before, to an instructor, who did not assist during the common pool resource experiment. The instructor was sitting at a nearby table ensuring that the right envelop was collected.

[19] The pilot experiment indicated that ostracism would most likely happen in the first period and this would have resulted in letting ostracized subjects sit and wait for 2.5 hours. By keeping the ostracized members waiting, there is a high possibility that they would be tempted to communicate with other subjects in the experiment. As a result, we decided to let the ostracized members leave the hall.

4.4 Results

In Figure 1, the time paths of the average time spent fishing in the two treatments are presented. The figure shows no significant difference between the two treatments during the first fifteen periods. However, after ostracism was introduced, the time spent fishing declined sharply towards the social optimum number of months compared to the baseline treatment. In both treatments, the time spent fishing started from a level slightly above the social optimum of 24 during the first periods and increasing over time in the experiment. The over-fishing increased over time and approached the Nash optimum of 6 months, which is consistent with previous findings in common pool resource experiments (e.g. Soest and Vyrastekova, 2004).

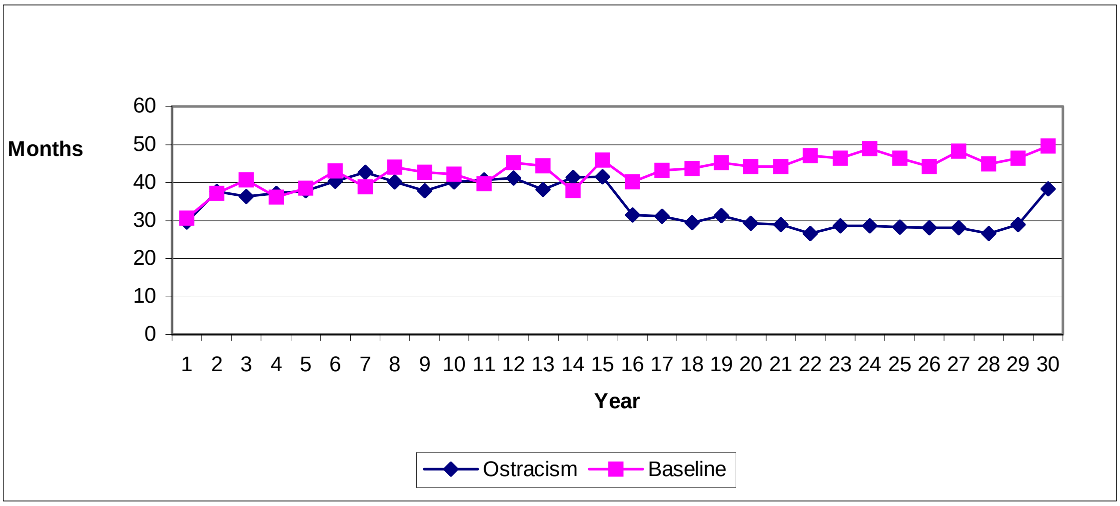

Figure 1: Average Number of Months of Fishing for the Two Treatments (i.e. Ostracism and Baseline). Note that the Social Optimum Corresponds to 24 months.

Using a two-tailed Mann-Whitney U-test, we cannot reject the null hypothesis that the average time fishing in the two treatments is the same during the first fifteen periods at 5% significance level. After the introduction of ostracism, the time spent fishing decreased in these groups to a level slightly above the social optimum number of months but statistically lower than the Nash equilibrium, while in the baseline treatment, the time spent fishing continues to slowly increase.[20] During the last fifteen periods, we can reject the null hypotheses that the two treatments are the same at 1% significance level using a two-tailed Mann-Whitney U-test, which indicates that the introduction of ostracism significantly affected the total time spent fishing.

Figure 2 shows the proportion of subjects who voted in the ostracism treatment, and the cumulative proportion of ostracized members. As shown in the figure, when the ostracism was introduced, 61% of the members voted in the first period to exclude another member in their group although exclusion was costly to the remaining members in the subsequent periods. Three subjects were ostracized in the first period, and additional two subjects during the following 14 periods. It should be noted that the subjects gained some experience with the common pool experiment since they had taken part in the first 15 periods.

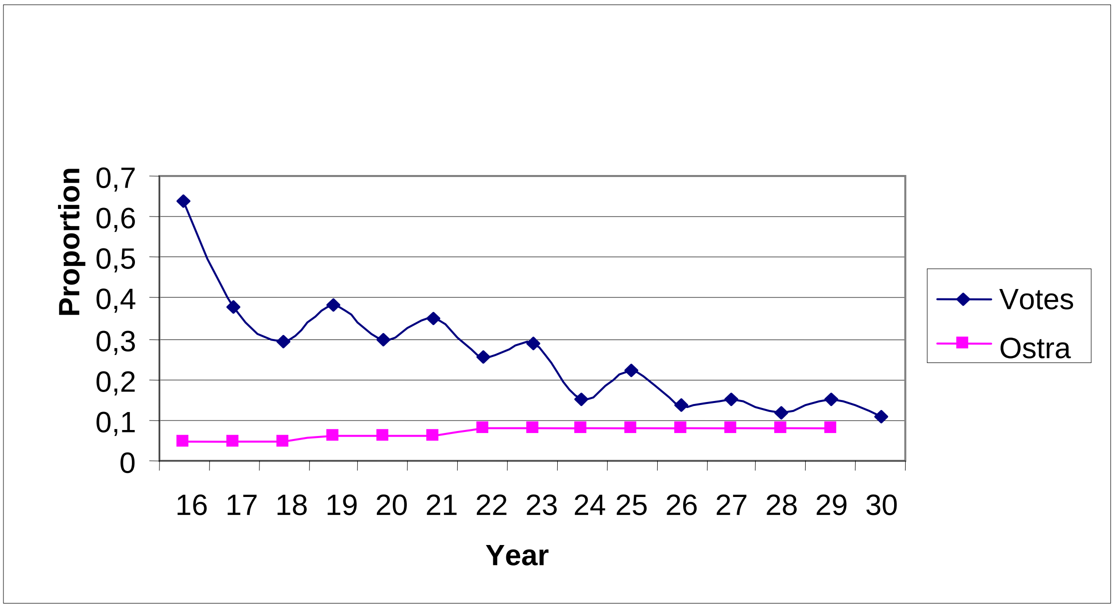

Figure 2: Cumulative Proportion of Ostracized Individuals and Proportion of Individuals Voting per Period

[20] The average was computed as the total effort per group divided by eight even if some member(s) had already been ostracized from the group. This approach is applied to make the results comparable between the baseline and the ostracism treatment. This is because while the individual optimal level of fishing has changed, the total social optimum level of fishing remains the same.

In the econometric analysis we study two aspects; votes received and changes in months fishing in the ostracism treatment. In Table 4, the number of votes received was regressed on *average months of fishing by others in previous year*, *positive deviation from group average* and *negative deviation from group average.* As expected, positive deviation has a positive and significant effect on votes received, while negative deviation has a negative and significant effect[21]. In Table 5, we show changes in months of fishing in the ostracism treatment. The only significant effect on the change in months of fishing was whether a subject, on the average, received a vote or not. The summary statistics of the variables used in the estimations are presented in Table 2, which is in Appendix I.

Table 4: Determinants of Votes Received: Regression Results for Round 18-29.

Average Months of Fishing by Others in the Previous Year or Round	0.038 (0.030)
Positive Deviation from Others' Group Average	0.424 (0.017)***
Negative Deviation from Others' Group Average	-0.057 (0.024)**
Constant	-0.336 (0.121)***
Observations	715
Number of Subjects	61
R-squared	0.59

Note. The standard errors are in parentheses.*,**,*** significant at 10%, 5% and 1% respectively. Group dummies have been included in the regressions to control for group fixed effects.

[21] We also estimated the model with a binary dependent variable of whether the individual received a vote or not but the regression had a lower explanatory power relative to the case where the dependent variable is continuous.

Table 5: Determinants of Change in Months of Fishing: Regression Results for Round 18-29.

	Model 1	**Model 2**
Average Months of Fishing by Others in Previous Year or Round	-0.139 (0.088)	-0.144 (0.083)
Votes Received	-0.676 (0.82)***	-0.697 (0.090)***
Female		0.014 (0.113)
Membership		- 0.020 (0.053)
Low Fishing Intensity		0.109 (0.107)
Trust		0.010 (0.042)
Violated Fishing Law		-0.186 (0.143)
Constant	0.651 (0.325)**	0.601 (0.341)*
Observations	835	835
Number of Subjects	61	61
R-squared	0.08	0.08

Note. The standard errors are in parentheses.*,**,*** significant at 10%, 5% and 1% respectively. Group dummies have been included in the regressions to control for group fixed effects.

4.5 Discussion and Conclusion

In this paper we have presented the results to show how the introduction of ostracism affects the amount of time spent on fishing in a common pool resource experiment, framed as a fishery problem among young fishers in Anyako, a fishing community in the Volta Region of Ghana. The fishery sector in Ghana is currently characterized by over-fishing, and a decentralized decision-making process where the chief fisherman acts both as the maker of traditional fishing laws and enforcer of the laws. The experiment shows that the introduction of the possibility of ostracizing members, based on a simple majority voting rule, significantly decreased over-fishing. Although it was costly for non-ostracized members to ostracize a member, coupled with the knowledge that the ostracized member would end up in poverty, ostracism took place. This finding is inline with e.g. Fehr and Gächter (2000) and Cinyabuguma et al. (2005) where subjects punished others although at a cost to themselves. Interestingly, of the 5 members who were ostracized, 3 were ostracized in the first period of the ostracism treatment indicating that some members did not expect the others to be that harsh.

However, self-reported rate on reporting violation of the fishing laws indicates that two-thirds of the subjects in our sample would always report violation. Part of the problem related to over-fishing might be due to inadequate punishment of over-fishers, and ostracizing a member from the community rarely takes place, or ostracized members quickly show remorse and are reaccepted back into the community. This may imply that the social ties are stronger than the concern for over-fishing. An example of the type of ostracism in our experiment could be a community based fishing licensing, which could be withdrawn (permanently) if a fisher violates a fishing law that is endogenously monitored. Fishing licenses exist in many developing countries in Africa and Asia (Srinivasan, 2002). Moreover, at the heart of the effectiveness of enforcement of fishing regulations with endogenous institutions is the availability of adequate and reliable data on fish stocks and harvest rates, which is taken for granted in our experimental settings.

4.6 References

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Appendix I

Table 1: The Number of Votes Required to be Ostracized and the Cost Imposed on Remaining Members

Number of Subjects Remaining	Number of Votes Required to be Ostracized	Cost from Exclusion on the Remaining Subjects
8	4	0
7	4	27
6	3	56
5	3	76
4	2	114
3	2	169

Table 2: Descriptive Statistics of Explanatory Variables

Variable	Description	Mean	Std. Dev.
Average Months Fished by Others		4.77	1.20
Votes Received		0.24	0.64
Female		0.34	0.47
Membership		2.13	1.26
Low Fishing Intensity	Fished at most 21 days during a month	0.75	0.43
Trust	Trust in other students measured on a scale from 1 to 5	2.95	1.40
Violated Fishing Law	1 if violated fishing law during the last 12 months.	0.27	0.44

Table 3*:* The Relative Frequency of Months of Fishing.

Months	Period 2-15 Ostracism Treatment	Baseline Treatment	Period 16-29 Ostracism Treatment	Baseline Treatment
0	0 %	0 %	6.8 %	0 %
1	1.2 %	0 %	1.5 %	0.1 %
2	10.9 %	7.9 %	12.7 %	6.5 %
3	15.3 %	17.5 %	22.4 %	11.8 %
4	16.2 %	15.9 %	26.7 %	11.0 %
5	14.1 %	14.7 %	15.6 %	12.4 %
6	13.4 %	14.6 %	7.5 %	14.7 %
7	13.2 %	13.8 %	4.0 %	16.6 %
8	15.7 %	15.5 %	2.8 %	26.8 %
	100 %	**100 %**	**100 %**	**100 %**

Appendix II

INSTRUCTIONS FOR THE EXPERIMENT

Hello, and thank you for coming here today. Please read through these instructions carefully. **DO NOT DISCUSS THE EXPERIMENT WITH OTHERS IN THE ROOM**. If you have any questions, please feel free to raise your hand and an instructor will come and help you. Before the experiment begins, everyone will be given the opportunity to ask questions. Once the experiment has begun, you may still raise your hand if you have a question. Talking with others during the experiment is **NOT** permitted. If you do, you will be asked to leave the room and forfeit all your earnings.

In each round of the experiment, you have the opportunity to earn cash in Experimental Currency Units (ECU). The experiment has two parts with each part consisting of 15 rounds. Once the experiment is over, we will compute your total earnings for both parts. The following day **all of you will be paid in cash.** You will be paid the Cedis equivalent of your experimental earnings at an exchange rate of **1 ECU = 35 Cedis in Cash.** The more you make in ECU, the more you will make in Cedis. We will ensure that none of the other students in the experiment knows how much you earned. You will need your ID to collect your earnings the following day so keep it until you collect the cash.

Introduction

In this experiment you and **seven** others in this room will make a series of decisions on how many months to fish in a year. In any one year, you can fish up to a maximum of 8 months but the quantity of fish you harvest will depend on the number of months the other members of your group harvest from the fishery. In each round, which corresponds to a year of fishing, you will have to decide, and declare, how many months you will spend in the fishery.

The Payoff Table

At the start of the experiment, you will receive a PAYOFF TABLE that should be read the same way as the one attached to the end of these instructions. All participants will have the same payoff table as you. This table contains all the information that you need to make your decision for each year of fishing. The **numbers that are in the table** correspond to the **ECU** that you would earn in each year for a given set of decisions. Each of you must decide the number of MONTHS that you want to spend in the fishery (in the columns from 0 to 8).

To harvest in each round you must write the number of the current round and the number of months you have decided upon (this will be a number between 0 and 8) on an EXPERIMENTAL CARD that the instructor will give to you. There is an example attached to the end of the instructions.

After everyone has made his/her decision, the instructor will collect the EXPERIMENTAL CARDS from all 8 members of the group and will calculate the total number of months that the group decided to spend extracting from the fishery. When the instructor announces the group total, each of you will be able to calculate the ECU that you earned in that round. You will find an example below.

In this experiment, we assume that each individual has a maximum of 8 MONTHS each year to extract fish. On the PAYOFF TABLE, this corresponds to the columns from 0 to 8. Each of you must decide on the number of months, from 0 to 8, that you fish in each year. But to be able to know how much you earned in ECU, you need to know the decisions that the rest of the group made.

Table 1: An Example of How the Payoff Table Works

		My Months In The Fishery								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Their Months In The Fishery	**19**	49	52	55	58	60	63	64	66	67
	20	47	51	**53**	56	59	61	62	64	65
	21	46	49	52	54	57	59	60	62	63
	22	45	48	50	53	55	57	58	60	61

1. You decide that "**My Months In The Fishery**" will be 2.
2. The instructor collects all the Decision Cards and gives you a written feedback on the number of months each ID number spent in the fishery and the TOTAL number of months your group spent in the fishery.
3. Assuming that a TOTAL of 22 months were spent in the fishery, you know that "Their months in the fishery" was 20, and your earnings for the round are 53 ECU.

The First Record Sheet

OK, let us look at how the experiment works in each round (i.e. each year). Each participant will receive a FIRST RECORD SHEET like the one attached to the end of these instructions.

Using Example 1 above, let us see how to use this FIRST RECORD SHEET. Suppose that you decided to spend 2 months in the fishery this round. On the EXPERIMENTAL CARD, you should write 2 next to "My months in the fishery." You must also write this number in the first column (A) of the FIRST RECORD SHEET. (You must write your decision down in 3 places: the EXPERIMENTAL CARD that you give to the instructor, the FIRST RECORD SHEET and the SECOND RECORD SHEET you hang onto …).

The instructor will collect the EXPERIMENTAL CARDS from everyone in your group and will calculate the total number of months spent in the fishery by the whole group. The instructor will give everyone in the group written feedback on the number of months that each ID number in your group spent in the fishery and the TOTAL number of months that your group spent in the fishery. Suppose that the total was 22 months. Write 22 in column B of the FIRST RECORD SHEET. To calculate "Their months in the fishery", subtract column A from column B, and record this in column C. In our example, "their months in the fishery" is 20. To calculate your earnings, use the payoff table described earlier. If "my months" equals 2, and "their months" equals 20, then your earnings would be 53 ECU. In this example, you would have written the following on your FIRST RECORD SHEET:

FIRST RECORD SHEET ID: ______________________________				
	Column A	**Column B**	**Column C**	**Column D**
Round No.	**My Months in the Fishery** (Your Decision)	**Total Group Months in the Fishery** (Given by the Instructor)	**Their Months in the Fishery** (Column B minus Column A)	**My Earnings in this Round (ECU)** (Use your PAYOFF TABLE)
1	2	22	20	53
2				

Second Record Sheet:

It is very important to clarify that nobody will know what your decisions were in each year or what you have earned from the experiment because only your ID number will be used throughout. Written feedback on both the **group total** and the months spent in the fishery by each ID number in your group will be given to you at the end of each round by the instructor. Record the **individual months** and the **group total** on the SECOND RECORD SHEET below. The instructor will collect this record sheet at the end of the experiment.

ROUND	**SECOND RECORD SHEET** **ID______________________________** **INDIVIDUAL NUMBER OF MONTHS (Please Record for each Round)**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Group Total**
1									
2									
3									
4									
5									
. . .									
30									

If you have any questions about how to earn money in the experiment, please ask before the experiment begins.

Summary of Steps for Harvesting One Round of the Experiment

How it is Done: In each round, you must decide how many months, between 0 and 8, you want to devote in one year to extracting resources from a fishery. Your earnings in each round depend on both your decision and the decisions made by the other members of your group, according to the PAYOFF TABLE.

What you need: To take part, you need a PAYOFF TABLE, FIRST RECORD SHEET, SECOND RECORD SHEET, and EXPERIMENTAL CARDS. You also need an **ID number**. The instructor will provide all of these.

Steps for Each Round

1. Using the **PAYOFF TABLE (given to you),** decide how many months you will spend in the fishery.

2. On the **FIRST RECORD SHEET,** write **your decision** (My Months in the Fishery) in Column A for the current round.

3. On an **EXPERIMENTAL CARD,** write the round number, and your decision (My Months in the Fishery). Make sure it corresponds exactly to what you wrote on the FIRST RECORD SHEET. Hand the experimental card to the instructor.

4. The instructor will collect all the experimental cards and give you written feedback on the **TOTAL GROUP MONTHS** and **INDIVIDUAL MONTHS.**

5. On the **FIRST RECORD SHEET,** write this total in Column B (Total Group Months in the Fishery).

6. On the **FIRST RECORD SHEET,** calculate Column C (Their Months in the Fishery). This equals Column B minus Column A.

7. On the **FIRST RECORD SHEET,** write in Column D the total amount in ECU that you earned in this round. To know how much you earned, use the PAYOFF TABLE and columns A and C (My Months and Their Months).

8. On the **SECOND RECORD SHEET**, write down individual months, which were given by the instructor for each round.

9. Harvest another round (Go back to step 1).

FIRST RECORD SHEET NAME: ______________________________ ID: _______				
	Column A	**Column B**	**Column C**	**Column D**
Round No.	**MY MONTHS IN THE FISHERY** (From your Decision)	**TOTAL GROUP MONTHS IN THE FISHERY** (Given by the Instructor)	**THEIR MONTHS IN THE FISHERY** (Column B minus Column A)	**MY EARNINGS IN THIS ROUND** (Use your PAYOFF TABLE)
1				
2				
3				
…				
30				
			TOTAL	

EXPERIMENTAL CARD	
ID:	
Round Number:	
My Months in the Fishery:	

PAYOFF TABLE

THEIR MONTHS IN THE FISHERY	MY MONTHS IN THE FISHERY								
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
0	0	26	52	78	104,1	130,1	156,1	182,1	208,1
1	0	26	52	78	104,1	130,1	156,1	182,1	208,1
2	0	26	52	78	104,1	130,1	156,1	182,1	208,1
3	0	26	52	78	104,1	130,1	156,1	182,1	208,1
4	0	26	52	78	104,1	130,1	156,1	182,1	208,1
5	0	26	52	78	104,1	130,1	156,1	182,1	208,1
6	0	26	52	78	104,1	130,1	156,1	182,1	208,1
7	0	26	52	78	104,1	130,1	156,1	182,1	208,1
8	0	26	52	78	104,1	130,1	156,1	182,1	208,1
9	0	26	52	78	104,1	130,1	156,1	182,1	208,1
10	0	26	52	78	104,1	130,1	156,1	182,1	208,1
11	0	26	52	78	104,1	130,1	156,1	182,1	208,1
12	0	26	52	78	104,1	130,1	156,1	182,1	208,1
13	0	26	52	78	104,1	130,1	156,1	182,1	208,1
14	0	26	52	78	104,1	130,1	156,1	182,1	208,1
15	0	26	52	78	104,1	130,1	156,1	182,1	208,1
16	0	26	52	78	104,1	130,1	156,1	182,1	208,1
17	0	26	52	78	104,1	130,1	156,1	182,1	193,3
18	0	26	52	78	104,1	130,1	156,1	169,2	179,7
19	0	26	52	78	104,1	130,1	145	157,2	167
20	0	26	52	78	104,1	120,8	134,7	146,1	155,3
21	0	26	52	78	96,7	112,3	125,3	135,9	144,3
22	0	26	52	72,5	89,8	104,4	116,5	126,3	134,1
23	0	26	48,3	67,4	83,5	97	108,2	117,4	124,6
24	0	24,2	44,9	62,6	77,6	90,2	100,6	109	115,6
25	0	22,5	41,8	58,2	72,2	83,8	93,4	101,2	107,2
26	0	20,9	38,8	54,1	67,1	77,9	86,7	93,8	99,3
27	0	19,4	36,1	50,3	62,3	72,3	80,4	86,9	91,8
28	0	18	33,5	46,7	57,8	67	74,5	80,4	84,8
29	0	16,8	31,1	43,4	53,6	62,1	68,9	74,2	78,1
30	0	15,6	28,9	40,2	49,7	57,4	63,6	68,4	71,8
31	0	14,5	26,8	37,2	45,9	53	58,6	62,8	65,8
32	0	13,4	24,8	34,4	42,4	48,8	53,9	57,6	60,1
33	0	12,4	23	31,8	39,1	44,9	49,4	52,6	54,7
34	0	11,5	21,2	29,3	35,9	41,1	45,1	47,9	49,6
35	0	10,6	19,5	26,9	32,9	37,6	41	43,4	44,6
36	0	9,8	18	24,7	30,1	34,2	37,2	39,1	39,9
37	0	9	16,5	22,5	27,4	31	33,5	35	35,5
38	0	8,2	15	20,5	24,8	27,9	30	31	31,2
39	0	7,5	13,7	18,6	22,3	25	26,6	27,3	27,1
40	0	6,8	12,4	16,7	20	22,2	23,4	23,7	23,1
41	0	6,2	11,2	15	17,7	19,5	20,3	20,2	19,3
42	0	5,6	10	13,3	15,6	16,9	17,3	16,9	15,7
43	0	5	8,9	11,7	13,5	14,5	14,5	13,8	12,2
44	0	4,4	7,8	10,1	11,6	12,1	11,8	10,7	8,9
45	0	3,9	6,8	8,7	9,7	9,8	9,2	7,8	5,7
46	0	3,4	5,8	7,3	7,9	7,7	6,7	5	2,6
47	0	2,9	4,8	5,9	6,1	5,6	4,3	2,2	-0,4
48	0	2,4	3,9	4,6	4,4	3,5	1,9	-0,4	-3,3
49	0	2	3,1	3,3	2,8	1,6	-0,3	-2,9	-6,1
50	0	1,5	2,2	2,1	1,3	-0,3	-2,5	-5,3	-8,8
51	0	1,1	1,4	1	-0,2	-2,1	-4,6	-7,7	-11,4
52	0	0,7	0,6	-0,2	-1,7	-3,8	-6,6	-9,9	-13,9
53	0	0,3	-0,1	-1,2	-3	-5,5	-8,5	-12,1	-16,3
54	0	-0,1	-0,8	-2,3	-4,4	-7,1	-10,4	-14,3	-18,6
55	0	-0,4	-1,5	-3,3	-5,7	-8,7	-12,2	-16,3	-20,9
56	0	-0,8	-2,2	-4,3	-6,9	-10,2	-14	-18,3	-23,1

Paper 5

The Environment as a Public Good and Internalized Contribution Norms

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Abstract

This paper links a utility theoretical model based on internalized norms, influenced by Bowles and Gintis (2005), with the results from a novel public goods experiment in Ghana. The results indicate that, on average, people are motivated by conditional cooperation of two kinds: people want to contribute more if others have contributed more in the previous round, and people want to contribute more if others are expected to contribute more. We also found evidence of learning, in the sense that people's contribution decrease over time even when others' contribution is held constant.

Keywords: Contribution Norm, Altruism, Public Goods.

***JEL** Classification*: D63; D64; H41

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5.1 Introduction

The environment has largely a public good character. Traditionally, environmental economics has focused almost exclusively on economic (i.e. monetary) policy instruments, together with command and control policy and property right issues, when analyzing the free-riding behavior which is assumed to result from this public good character (Baumol and Oates, 1988; and Hanley et al., 1997). However, recent experimental results indicate that people under some conditions free-ride to a much lower degree than what standard economic theory predicts (Gintis et al., 2005). Various kinds of informal norms, for example, based on reciprocity and perceived fairness, are likely explanations (Camerer, 2003; Fehr and Fischbacher, 2004; Fehr and Gächter, 2000; Ostrom, 1990; and Ostrom et al., 1994). With respect to the environment, such norms can be expected to be particularly important for developing countries. This is based on two reasons: 1. Environmental and natural resource factors are typically very important production inputs in developing countries. 2. The legal institutions are typically weak in these countries.

This paper presents a simple public goods experiment designed to capture some of the important characteristics of environmental and natural resource problems in many developing countries with poorly working formal institutions. First, it is performed in a developing country (Ghana). Second, it acknowledges that an individual's behavior is often difficult to be observed by others; hence our experimental design ensures individual anonymity.[1] Third, the environmental outcome typically depends on repeated interactions between people. However, the repetitions are typically not made infinitely, or very many times, with the same people involved. This implies that, the so called folk theorem (Fudenberg and Maskin, 1986) is of little help. Moreover, it takes into account that an individual interacts with different people, and experiences from interaction with a group of people will spill over into an individual's behavior if she interacts with another group.

[1] This does not imply that it is always impossible to observe the behavior of others with respect to the environment, or that the social disapproval effect is unimportant; cf. Rege and Telle (2004) and Masclet et al. (2003).

There is massive evidence that people cooperate in one-shot public good experiments (or voluntary contribution mechanisms), despite the opposite prediction from conventional economic theory; see Dawes (1980), Ledyard (1995) or Zelmer (2003) for extensive surveys. It has also been found that people's contributions decrease gradually towards the Nash prediction when the game is played repeatedly. For a long time this was seen as evidence of individual errors and learning, i.e. people's behavior converges towards the conventional Nash prediction due to learning. However, it seems these conclusions were premature. Conditional cooperation is instead the main (or at least an important) driving force behind the observed pattern (Fischbacher et al., 2001). Thus, according to this view, many people want to cooperate, but only if others cooperate too.

In this paper, we present a simple utility theoretical framework, which builds on a recent model by Bowles and Gintis (2005), where people derive utility from fulfilling a social norm. This norm, in turn, is affected by both the expected contributions of others and others' actual contributions in the previous round. We directly estimate the parameters of the assumed utility function based on the results from our experiment. We use a standard two-round public good experiment based on 12 groups with 4 people in each group. After the first round, the members in each group get information about the average contribution of others in their own group. Then the game is played a second (and last) time. After this, there is a surprise re-start with re-matching, and two additional rounds are played. We also vary the exchange rate between public and private money between the groups. In principle, we are able to estimate five separate components:

i. How much higher an individual's contribution would have been if the average contribution of others in the group would have been one token higher.

ii. How much higher an individual's contribution would have been if the average contribution of others in the group that the individual belonged to in the previous round would have been one token higher.

iii. How much the exchange rate from private to public money affects the contribution.

iv. How large the size of the 'ethically ideal contribution level' if others do not contribute anything is.

v. How large the effects of potential learning are, i.e. to what extent does the contribution decrease towards the Nash prediction over time holding others' behavior fixed.

To our knowledge, these motives have not been analyzed simultaneously before. In section 5.2, we present the experimental design. This is followed by the model and the corresponding hypotheses in section 5.3. Section 5.4 presents and discusses the results, whereas Section 5.5 provides the conclusion.

5.2 The Experimental Design

The experiment is based on standard linear public goods games with 4 players and each has an equal initial endowment of 10 units. Each player has to decide how much of the 10 units to allocate to a public good (the environment) and how much to keep for himself. The amount provided to the public good is multiplied by a constant 4*m*, such that $1 < 4m < 4$, and then shared equally. The payoff to an individual *i* is then given by $10 - x_i + m_i \sum_{j=1}^{4} x_j$. There were 12 groups that differed from each other with respect to the value of *m*. The subjects were informed that they should play this game twice with the same participants in the group. After each subject had made the decision, information on contributions by each member of a group was written and handed out to all the other members of the group. The experiment was completely anonymous, meaning each individual had no information regarding the other three subjects that he was playing with among the remaining 47 potential participants in the room. Then each subject made a second decision about how much to contribute in the second round.

There was a surprise restart after that, and a complete re-matching and two more rounds with new *m*-values were played. The subjects were informed that there would be no further subsequent surprises. Let us denote the rounds A1, A2, B1 and B2, respectively. The value of *m* varied among the groups ranging from 0.3 to 0.9, which implies the exchange rate between public and private money *4m* varies between 1.2 to 3.6; and each subject had a higher *m* in B than in A (see Table A in Appendix I for further information). As specified in the instruction, a dice was tossed and the outcome was used to determine which of the set of decisions in the two sections (i.e. section A or B) was to be used for the eventual payments. Thus, each subject made four sequential decisions (See Appendix II for the instructions of the experiment).

The experiment was conducted in a big classroom with 48 students from the University of Cape Coast in Ghana. There is hard competition to be accepted at the university, and there is no reason to expect these students to be less capable than students in western countries, on average. On the other hand, the students come from all over Ghana, and many of them come from families that are heavily dependent on natural resources for their living.

Participation was voluntary and the subjects were randomly selected from various programs. There was no show-up fee. Notices were posted at the halls of residence requesting volunteers to sign up and participate in an economic decision-making experiment from which there was an opportunity to earn cash. A hundred and thirteen students singed up. Out of this number, the first 48 were recruited for the experiment, which took place in a classroom. Each subject was given an identification number that was not known to any other participant. Moreover, the subjects were strongly prohibited to talk to one another throughout the experiment, and none did. The experiment began with a set of questions to train the subject to compute his/her earnings for various contribution profiles. A slightly shortened version of the question and information set used by Fischbacher et al. (2001) was used. To make the notion of the Nash equilibrium and social optimum contribution evident, each subject computed his/her earnings for two situations: if she contributed nothing and if she contributed her full endowment. When all the subjects successfully computed their earnings the actual experiment was administered. The experiment lasted for one-and-a half hours and at the end of the experiment all the subjects were paid the cash equivalent of the experimental units they won in the game. The mean earning was 9.83USD. This is a substantial amount compared to the favorable loans of about 6USD per week, given to the students to finance their living expenditures during the semesters. Consequently, the students were very focused during the experiments.

5.3 The Model

Admittedly, a model where utility is solely a function of individual payoff cannot explain the widespread observed experimental evidence that people tend to contribute non-negligible amounts in public good games.

5.3.1 Internalized Norms

Consequently, we hypothesize that people in addition to their own payoff care about an *internalized norm*, by which we, following Bowles and Gintis (2005) mean "a norm that one has accepted, not as a constraint, but rather as an *argument of one's objective function*" (italics in origin). Deviation from this norm causes a *psychic cost* to the individual. Also following Bowles and Gintis, we assume this cost is quadratic in the difference between a representative individual *i*'s contribution x_{it} to the environment and his contribution norm x_{it}^{*} at time *t*, and this cost can be imposed additively to the payoff in the utility function as follows:

$$u_{it} = \omega - x_{it} + m_{it} \sum_{j=1}^{n} x_{jt} - \beta \left(x_{it} - x_{it}^{*} \right)^{2} \tag{1}$$

where $\beta \left(x_{it} - x_{it}^{*} \right)^{2}$ is the psychic cost. It is natural to interpret this cost in terms of guilt feelings if $x_{it} < x_{it}^{*}$ and as anger resulting from a perception that one has been cheated upon if $x_{it} > x_{it}^{*}$.[2] Note that we treat this utility function as purely ordinal, meaning any monotonic transformation of *u* is an equally valid utility function.

[2] However, Bowles and Gintis (2005) interpret the psychic cost in terms of guilt in both cases. They argue that it is logical for an individual to also feel guilty if he contributes more than the norm, and if the amount the individual allocates to his private account is directed towards other *worthy* activities which he also has norms.

Consider next, the determinants of the norm itself. Given the likely importance of conditional cooperation (e.g. Fischbacher et al., 2001; Frey and Meier, 2004), it makes sense to assume that the norm is positively related to others' contributions. There is also evidence from "think-aloud" methodology that people in environmental valuation studies seem to be influenced by others' contributions (Schkade and Payne, 1994).

However, conditional cooperation can be either backward or forward-looking. That is, I may want to be nice to someone because he was nice to me in the last round, or I may want to be nice to someone because I expect that he will be nice to me. Moreover, the norm may be influenced by other factors besides conditional cooperation. For example, there is much evidence that most people seem to believe they are superior to other people (on average) in many dimensions, including generosity; see Taylor and Brown (1994) or Baumeister (1998) for overviews, and Johansson-Stenman and Martinsson (2005) who found that most people believe they vote more based on what is good for the society overall, and less selfishly, than others. If so, it is possible the contribution norm is larger than the expectation of others' average contribution, which would also imply that the contribution norm would be positive even when others are expected to contribute nothing. Then we can write:

$$x_{it}^{*} = \gamma E(\bar{x}_{-i,t}) + \lambda \bar{x}_{-i,t-1} + x^{0} \tag{2}$$

where $E(\bar{x}_{-i,t})$ is i's expectation of others' average contribution in time t, $\bar{x}_{-i,t-1}$ is others' actual average contribution in time *t-1* and x^{0} is the norm if others have contributed, and are expected to contribute nothing. Substituting (2) into (1) implies:

$$u = \omega - x_{it} + m_{it}\sum_{j=1}^{n} x_{jt} - \beta\left(x_{it} - \gamma E(\bar{x}_{-i,t}) - \lambda \bar{x}_{-i,t-1} - x^{0}\right)^{2} \tag{3}$$

Individual i's *best response* is obtained by maximizing (3) with respect to his contribution x_{it}, and solving for x_{it}:

$$x_{it} = x^0 - \frac{1}{2\beta} + \frac{m_{it}}{2\beta} + \gamma E(\overline{x}_{-i}, t) + \lambda \overline{x}_{-i,t-1} \tag{4}$$

5.3.2 Learning

Let us now for comparison reconsider the learning explanation of the observed behavior in public goods experiments. Assume the following ordinal utility function:

$$u_{it} = \omega - x_{it} + m_{it} \sum_{j=1}^{n} x_{jt} - \rho\left(x_{it} - \hat{x}_{it}\right)^2 \tag{5}$$

where $\hat{x}_{it}$ is a cognitive anchor that influences the individual decision (cf. Tversky and Kahneman, 1974). Note that utility in (5) reflects *decision* utility (Kahneman et al., 1997), and the *experienced* utility here is assumed to solely depend on monetary payoff, i.e. the first three terms. For analytical simplicity, we model learning as a simple linear process as follows:

$$\hat{x}_{it} = \hat{x} - \varsigma t \tag{6}$$

as long as $\hat{x}_{it} > 0$, otherwise $\hat{x}_{it} = 0$. Substituting (6) into (5) gives:

$$u_{it} = \omega - x_{it} + m_{it} \sum_{j=1}^{n} x_{jt} - \rho\left(x_{it} - \hat{x} + \varsigma t\right)^2 \tag{7}$$

The individual behavior is, by definition, characterized by maximizing decision utility.

Maximizing (7) and solving for x_{it} gives:

$$x_{it} = \hat{x} - \frac{1}{2\rho} + \frac{m_{it}}{2\rho} - \varsigma t \tag{8}$$

5.3.3 Empirical Model and Hypotheses

We are interested in estimating the parameters of a "representative individual's" utility function. In the empirical analysis of the data we run the following straightforward OLS regression:

$$x_{it} = \alpha + \mu m_{it} + \sigma \bar{x}_{-i,t-1} + \tau D \bar{x}_{-i,t-1} + \upsilon t + \varepsilon \tag{9}$$

where x_{it} is *i*'s contribution in round *t* and ε is assumed to be approximately normally distributed, which may reflect both decision errors and preference heterogeneity. Let us also assume that others' average contribution in the previous round, $\bar{x}_{-i,t-1}$, is a good approximation for the expectation of others' average contribution. *D* is a dummy variable which equals 1 for *t* = 3 (round B1), i.e. when the individual changes group. The interpretation of τ is thus the additional effect that an increase in others contribution have in round B1, compared to the corresponding effects in round A2 or B2. For example, if $\tau < 0$ it implies that others' previous contribution have a lower impact on own contribution in round 3, presumably due to the fact that there is no reciprocity motive (cf. Fehr and Gächter, 2000) in this round.[3]

The parameter υ reflects possible learning. Thus, if $\upsilon < 0$ the contribution decreases over time (i.e. is lower in a later round) even if others' previous contributions are corrected for. Straightforward identifications give $\beta = \frac{1}{2\mu}, \gamma = \sigma$ and $x^0 = \alpha + \frac{1}{2\beta}$. From the reasoning above, based on our theoretical model, we have the following testable hypotheses:

H1. People are motivated by fulfillment of an internalized norm, so that $\beta = \frac{1}{2\mu} > 0$, and people's behavior cannot be explained by learning, so that $\upsilon = 0$.

[3] Alternatively, strategic consideration could give rise to a different pattern with or without a restart, since there are no strategic reasons to contribute in the last round with the same co-players. However, since each individual only plays two rounds within each group, the strategic motive is presumably weak.

H2. People are motivated by conditional cooperation, meaning they will contribute more if they expect others to contribute more, so that $\gamma = \sigma > 0$.

H3. People are motivated by reciprocity, so that $\tau < 0$.

H4. People's contribution norm is positive even when others are not expected to contribute anything, or have contributed nothing in the previous round, so that $x^0 = \alpha + \frac{1}{2\beta} > 0$ (ignoring possible learning effects).

H5. (The main competing hypothesis). The contributing behavior can be explained by learning, so that $\upsilon < 0$ and $\sigma = \tau = 0$.

5.4 Results

The mean contributions of the four rounds were 5.91, 5.32, 4.72 and 4.52. Based on paired t-tests the mean of A1 (i.e. 5.91) is significantly higher than that of the B1 (i.e. 4.72) ($p > 0.006$). However, we cannot reject the hypothesis that the means of the first two rounds (i.e. A1 and A2), the last two rounds (i.e. B1 and B2) and the second and third rounds (i.e. A2 and B1) are equal. Moreover, the Mann-Whitney U test, which is a non-parametric test, is consistent with paired t-tests, albeit weak significantly higher mean of A1 relative to the B1 ($p > 0.058$). Thus, although the mean contribution of the first rounds of the two sections are significantly different, there was no significant difference between the round before the group was changed and the first round after the group was changed, which seems to indicate that past experiences influence present behavior even in an unrelated environment.

The frequency distributions averaged over all four rounds is presented in Figure 1. Overall, full cooperation was obtained in about 20% of the cases, whilst the extreme self-interestedness (i.e. the conventional Nash prediction) was obtained in only 7% of the cases.

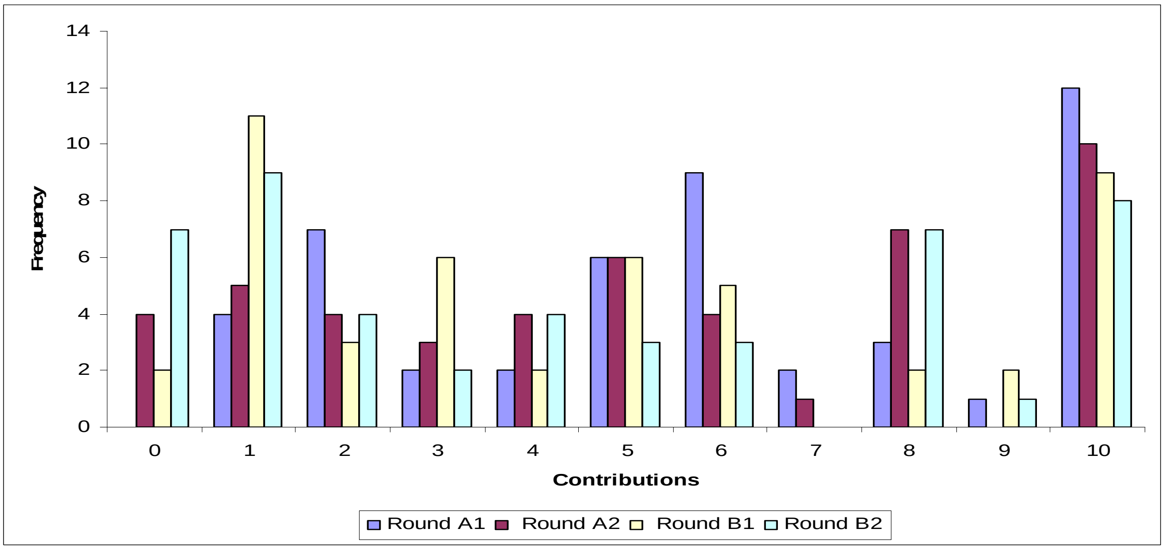

Figure1: Frequency Distribution Across Rounds

Table 1 presents the results of our estimations. The first estimation, which is in the column denoted (1) in the table, does not control for possible learning effects (i.e. the time trend) or the effect of change of group on individual contributions. The second estimation includes the learning effect but not the group switch effect. The third estimation includes both the learning effect and the group switch effect. A likelihood ratio test indicates that we can reject the more restrictive model (1) in favor of model (3) with $p < 0.04$, but we cannot reject model (2) in favor of model (3) at $p < 0.1$. That people are motivated by a social norm (*H1*) implies the coefficient associated with the marginal benefit of contributing should be positive, which we obtained, although it is only statistically significant at conventional levels in models (2) and (3). A positive effect of the exchange rate between public and private money has also been found in many other studies; see e.g. Zelmer (2003) for a meta-analysis of public good games. The coefficient of the expected average contribution of others in the preceding round (i.e. σ) is positive and statistically significant (two-sided tests) supporting the conditional cooperation hypothesis (*H2*). A coefficient of 0.32 implies a subject would contribute 0.32 units if others had contributed 1 unit more in the last round. The reciprocity hypothesis (*H3*) implies that the change of group effect should be negative, which is obtained, although not significant at conventional levels. The parameter value of -0.156 indicates that roughly half of the observed conditional cooperation effect appears to be due to reciprocity, i.e. backward looking, and consequently that half is due to expectations, i.e. forward looking. The intercept is positive, as it should be according to the hypothesis that people have a positive contribution norm even when others do not contribute anything (*H4*), but it is only significant in models (2) and (3). Thus, so far the results seem quite supportive of our main model.

However, from models (2) and (3) it can be observed that the time trend is negative and significant. This implies that the second part of *H1* is not fulfilled. Thus, our main model which is built on Bowles and Gintis (2005) is not sufficient to explain observed behavior. The size of the parameter, which is about unity, indicates that everything else constant, a subject would contribute about one unit less per round. The first part of the competing learning hypothesis (*H5*) is thus fulfilled, although learning can obviously not explain the whole story either, and the second part of *H5* is hence not fulfilled. This result mimics the findings of Croson et al. (2005), who also found that people's contribution decreases over time even when other's contribution has been controlled for, but learning is an insufficient explanation.

Table 1: Ordinary Least Square (OLS) Regression of Determinants of Own Contribution

Independent Variable	**(1)**	**(2)**	**(3)**
Average Contribution of Others in Previous Round	0.377 0.154)**	0.297 (0.157)*	0.321 (0.155)**
Marginal Benefit of Contributing to Pubic Good	2.375 (1.699)	5.256 (2.130)**	6.688 (2.273)***
Time Trend		-0.967 (0.452)**	-1.139 (0.448)**
Change of Group Effect			-0.156 (0.101)
Constant	1.427 (1.180)	3.135 (1.481)**	2.983 (1.480)**
Observations	144	144	144
R-squared	0.060	0.090	0.102

Likelihood Ratio (LR) Test for Nested Models:

- H_0: (2) nested in (3) .LR $\chi^2(1) = 1.88$, $P > \chi^2 = 0.17$
- H_0: (1) nested in (3) . LR $\chi^2(2) = 6.67$, $P > \chi^2 = 0.04$
- H_0: (1) nested in (2) . LR $\chi^2(2) = 4.80$, $P > \chi^2 = 0.03$

* Significant at 10%; ** significant at 5%; *** significant at 1%. Robust standard errors are in parentheses.

5.5 Conclusion

The results from our experiment are consistent with a model, which indicates that people care about fulfilling a social norm that in turn depends on others' historical contributions as well as expected contributions. However, the results also seem to imply that learning played a role, i.e. contribution decreased over time, ceteris paribus.

When considering potential implications for environmental policy, one must bear in mind that the external validity is always an issue with economic experiments. However, if one is willing to take the risk of generalizing some insights more broadly, an implication is that one should not solely focus on monetary incentives, but also consider intrinsic motivations in environmental policy. More specifically, the perceived fairness of environmental policy is likely to affect people's willingness to comply. Moreover, the results obtained do not imply that voluntary contribution would in any way be sufficient. On the contrary, in a situation with a high degree of anonymity, it can be expected that people's cooperative behavior will deteriorate over time, resulting in excessive environmental damage. Thus, an important policy instrument may be to try to reduce the extent to which people can act anonymously, e.g. by publicly providing various kinds of information on individual behavior.

5.6 References

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Appendix I

Table A: Subject ID and Two Randomly Assigned m_i **(i.e.** m_1 **,** m_2 **)**

Subject ID	*m* in A1 and A2	*m* in B1 and B2	Subject ID	*m* in A1 and A2	*m* in B1 and B2	Subject ID	*m* in A1 and A2	*m* in B1 and B2
1	0,3	0,4	**17**	0,4	0,5	**33**	0,5	0,6
2	0,3	0,5	**18**	0,4	0,6	**34**	0,5	0,7
3	0,3	0,6	**19**	0,4	0,7	**35**	0,5	0,8
4	0,3	0,7	**20**	0,4	0,8	**36**	0,5	0,9
5	0,3	0,4	**21**	0,4	0,5	**37**	0,5	0,6
6	0,3	0,5	**22**	0,4	0,6	**38**	0,5	0,7
7	0,3	0,6	**23**	0,4	0,7	**39**	0,5	0,8
8	0,3	0,7	**24**	0,4	0,8	**40**	0,5	0,9
9	0,3	0,4	**25**	0,4	0,5	**41**	0,5	0,6
10	0,3	0,5	**26**	0,4	0,6	**42**	0,5	0,7
11	0,3	0,6	**27**	0,4	0,7	**43**	0,5	0,8
12	0,3	0,7	**28**	0,4	0,8	**44**	0,5	0,9
13	0,3	0,4	**29**	0,4	0,5	**45**	0,5	0,6
14	0,3	0,5	**30**	0,4	0,6	**46**	0,5	0,7
15	0,3	0,6	**31**	0,4	0,7	**47**	0,5	0,8
16	0,3	0,7	**32**	0,4	0,8	**48**	0,5	0,9

Appendix II

Sample instruction for a subject with $m_1 = 0.3$ and $m_2 = 0.4$

SECTION A

You are participating in an economic experiment. The instructions you are about to read are self-explanatory. Now that the experiment has begun, we ask that you do not talk to anyone. The participation in the experiment is voluntary. You will be presented with a scenario in which you can earn cash. Please hold on to the code number form since you will need this form when collecting your earnings.

During the experiment, any communication with other participants is strongly prohibited. Please raise your hand, if you have any question or if there is anything that is not clear to you. We will answer all your questions individually. It is very important that you follow this rule otherwise you will be excluded from the experiment.

In this experiment, you are matched with three other people so it is a group consisting of four members. The other group members are other participants. Except for us, nobody knows who is in your group.

You are a member of a group of four people. Each person has to decide on the division of 10 tokens. You can put these 10 tokens in a private account or you can invest them fully or partially in a project. Each token you do not invest in the project will automatically be transferred to your private account. From the token you invest in the project, each member will get the same payoff. Of course, you will also get a payoff from the tokens the other group members invest in the project.

For each group member, the income from the project will be determined as follows: Income from the project equals the sum of the contributions to the project times **0.3.** For example, if the sum of all contributions to the project is 30 tokens, then you and all others will get a payoff of **30 * 0.3 = 9.0** tokens from the project.

Your total income in tokens = (10-your contribution to the project)
+ (0.3 * the sum of all contributions to the project)

You will take the decision **two times** and the total amount of tokens you earn will be converted to Cedis at the following exchange rate: **1 token=3,000 Cedis**. After you take the first decision, you will be given information on the contributions that is made by each ID number in your group to the project.

As you know, you will have 10 tokens at your disposal in each of the two rounds. You can put them in a private account or you can invest them in a project.

How many of the 10 tokens do you want to invest in the project in this round?

____________________ Tokens (in integer numbers and, a number not less than 0 and not more than 10)

SECTION B

The instructions you are about to read are self-explanatory and similar to that of **Section A, except the fraction that multiplies the total contribution by all members of your group**. Now that the experiment has begun, we ask that you do not talk to anyone. This is the **LAST** section of the experiment**. A coin will be tossed to determine which one of the two decisions you made (i.e. decision in Section A and Section B) will be used to pay you in cash. The payment will be made at the end of this session.** Please hold on to the code number form since you will need this form when collecting your earnings.

During the experiment, any communication with other participants is strongly prohibited. Please raise your hand, if you have any question or if there is anything that is not clear to you. We will answer all your questions individually. It is very important that you follow this rule otherwise you will be excluded from the experiment.

In this experiment, you are matched with three other people so it is a group consisting of four members. The other group members are other participants. Except for us, nobody knows who is in the group. **<u>The group members are NOT the same as those in Section A</u>.**

You will be a member of a group of four people. Each person has to decide on the division of **10** tokens. You can put these **10** tokens in a private account or you can invest them fully or partially in a project. Each token you do not invest in the project will automatically be transferred to your private account. From the token you invest in the project, each member will get the same payoff. Of course, you will also get a payoff from the tokens the other group members invest in the project. **Please note that in Sections A and B below, you have different values that multiply the amount invested in the project**.

For each group member, the income from the project will be determined as follows: Income from the project equals the sum of the contributions to the project times **0.4.** For example, if the sum of all contributions to the project is **30** tokens, then you and all others will get a payoff of **30 *0.4 = 12.0** tokens from the project.

Your total income in tokens = (10-your contribution to the project)
+ (**0.4* the sum of all contributions to the project**)

You will take the decision **two times** and the total amount of tokens you earn will be converted to Cedis at the following exchange rate: **1 token=3,000 Cedis**. After you take the first decision, you will be given information on the contributions to the project that is made by each ID number in your group.

As you know, you will have **10** tokens at your disposal. You can put them in a private account or you can invest them in a project.

How many of the **10** tokens do you want to invest in the project?
____________________ Tokens (in integer numbers and, a number not less than 0 and not more than 10)