choice of remuneration regime in fisheries: the case of Hawaii's longline fisheries

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ABSTRACT

One of the most prominent features of remuneration in the Hawaii's longline fisheries industry has been the norm of share contract regimes. This paper investigates whether the use of share contract regime is positively correlated to increased economic returns. The principal-agent framework is applied to develop a theoretical model for the remuneration choice. Empirical estimation is conducted using a switching regression model that accounts for certain vessel characteristics effects on revenue, depending on remuneration regime used (i.e., share contract or flat wage), as well as the potential selection bias in the vessels' contractual choice. Key findings from counterfactual simulations indicate: (1) a negative selection into choosing share contracts, and (2) that flat wage vessels would experience significantly higher revenues if they switch to share contracts. Thus, even though the labor market in Hawaii's longline fisheries relies upon foreign crew members, the results suggest that it would benefit owners of flat wage vessels to apply share contracts to increase their revenues.

Keywords: Remuneration Regime; Longline Fisheries; Hawaii; Commercial Fisheries; Lay System; Crew Shares; Labor Contracts; Incentive Systems

JEL: L2, Q1, Q22, J41

Introduction

The choice of remuneration regime is a matter of great interest in fisheries. There are two main types of remuneration regime in fisheries: flat wage and share contract. In the flat wage regime, each crew is paid a fixed salary as compensation per pay period (e.g., a monthly salary). In the share contract regime[1], the crew receives a percentage of either the gross revenue or profit per fishing trip. One of the most distinguishing features of remuneration in fisheries has been the norm of share contract regime. Alternative remuneration regimes, such as fixed wage[2], can only be found in a few fleets around the world. Studies have theoretically shown that share contract regime is the optimal form of remuneration in fisheries (Sutinen, 1979; Plourde & Smith, 1989). However, there has been no empirical study to support this theory. The fact that fixed wage is surfacing in some types of fisheries in recent years opens up a series of new research inquiries. For example, one is prompted to ask questions like: Is the dominance of share remuneration coming to an end? Is the recent shift to fixed wage in some fisheries because of changes in some environmental parameters or is the use of share contract based on false beliefs all along?

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[1] In this paper, we do not distinguish the various levels of the share contracts. In other words, as long as the crew receives a certain percentage of the revenue or profit, we consider that as "share contract" since details of the share contracts are unavailable in the case of Hawaii's longline fisheries.

[2] The terms flat wage and fixed wage are used interchangeably in this paper.

In this study, we apply the principal-agent framework to develop a model on choice of remuneration regimes in fisheries. We show that fixed wage may be a better alternative to share contract under certain conditions. We then use the Hawaii longline fisheries as a case study to shed some light on the empirical relationship between remuneration regime and economic returns in fisheries as well as to provide some explanations on the recent shift from share contract regime to flat rate regime in fisheries.

A Literature Review on the Determinants of Remuneration Regime in Fisheries

Matthiasson (1997) has provided an excellent survey on remuneration practice in fisheries; his main conclusion is that share contract regime has been the dominant remuneration system. Other forms of remuneration, such as fixed wage, have also been applied in some fisheries though they have been short-lived (Matthiasson, 1997; Sutinen, 1979). Share contracts have also been the prevailing regime in the Hawaii longline fisheries until recent years. Azabou, Bouzaiane and Nugent (1989) attribute this general predominance for the following reasons:

i. Share contracts generate incentives for the crew to exert optimal fishing effort;

ii. Share contracts share risk between the owner and the crew;

iii. Share contracts use resources relatively better than fixed wage contracts, especially when taking into account the highly seasonal nature of fishery;

iv. Share contracts encourage team work and cooperation, which improve fishing productivity;

v. Share contracts combine the comparative advantages of owner and crew for a sharing of benefits. For instance, the owner may have better access to credit and to market opportunities, while the crew may be better fishermen.

Platteau and Nugent (1992) summarize and compare the comparative vulnerabilities between fixed wage and share contract systems (See Table 1). Clearly, the popularity of share contracts in fisheries can be attributed to the potential benefits from risk sharing and generating incentives.

The roles of incentives

Matthiasson (1997) has developed a theoretical model showing that pure share contract regime motivates crew to exert more effort than fixed wage or combination of fixed wage and share contract regime at every given wage level. This phenomenon can be attributed to incentives. First, it is very difficult for the owner to supervise the fishing operation while the vessel is out at sea unless the vessel is owner-operated. Moreover, the cost of supervision would be very high, if it is at all possible. The hired captain motivated by his share of the profit would ensure his crew fish hard. Second, a typical feature of fisheries is teamwork of which the amount of fish caught is determined by the effort of the entire crew; therefore, the marginal productivity of an individual fisherman can hardly be specified. Share contract gives the crew incentives to work for the common goal.

Risk sharing

In addition to incentive, risk behavior also plays a role in decision on remuneration in fishery. Platteau and Nugent (1992) point out that fishing is subject to three types of simultaneous risk: production risk, price risk, and asset risk. Production risk results from uncertainties in both weather and marine ecology. Price risk is due to volatile supply conditions. Asset risk arises from concern for loss of assets and human lives. Using share contracts can reduce the risk burden for both the vessel owner and crew. Thus, share contracts reveal the risk-averse behavior of the owner or crew. Due to technological changes, the role of labor relative to fishing productivity has become less important. Expectedly, the simplicity advantage of fixed wage may overcome the risk sharing effect of share contracts. Thus, fixed wage has become increasingly popular over time.

While risk sharing is the most cited explanation for the popularity of share contracts in fisheries, McConnell and Price (2006) have pointed out that there remains a number of questions to explore. First, for the share system to have emerged purely as a means of spreading risk, it must be the case that vessel owners are more risk-averse than fishermen. However, this method of risk diffusion might not be the only solution as owners may choose to diversify their investments through different species, in different locations and at different times. Second, despite the uncertainties and risks associated with fishing, not all of the owners choose to use share contract regimes.

Implications for modeling fishery remuneration choice

Share contracts serve two functions: (1) to diffuse risk and (2) to motivate crews to exert high levels of effort without direct owner supervision. Nevertheless, most theoretical models consider these two functions in isolation. Also, predictions from these two approaches are different. Sutinen (1979) assumes in his model that both the vessel owner and crew are risk-averse, that all other means of risk transferring are too costly, and that the transaction costs are negligible. Under these assumptions, a rational owner will choose some degree of share contract as risk is diffused among the crew, which reduces the cost of risk bearing and provides a work incentive that makes it less costly to generate a high desired level of performance from the crew. On the other hand, if transaction costs are significant, and if there exists other risk shifting means; then the fixed wage may be optimal.

Sutinen also shows that share contracts result in a higher level of employment and production. The economic reasoning for this is that the risk-averse owner must earn an income sufficiently above what he would earn in alternative settings as compensation for bearing the risk. As expected, the owner chooses a risk sharing alternative that minimizes the risk premium. In sharing risk, the owner would pay the crew members less than what it would cost him if he were able to bear that same risk himself. Accordingly, under a share contract regime, the unit cost of production is lower and output is higher compared to a fixed wage system. Plourde and Smith (1993) extend Sutinen's model by integrating an output market, biological equilibrium, and regulatory policy into their framework. They have shown that in regulated markets, a fixed wage scheme may be optimal and leads to higher returns to fisheries firms.

McConnell and Price (2006) (henceforth, MP (2006)) point out that incentive mechanisms are just as widely accepted as the risk sharing-based model. Matthiasson (1999) develops a model for Icelandic fisheries where skippers are paid by share subject to an agreed minimum without sharing operating costs. His key finding is that fixed wage and share contracts may coexist as an incentive contract when strategy-dependent skipper-specific costs are important. With regard to incentive mechanisms, the most relevant modeling technique is the principal-agent approach by MP (2006). In their model, there are two contracting agents: the vessel owner and crew. The contract consists of two parameters specifying the share of ex-post revenues and costs for the crew. The possibility that each crew member allocates his labor effort independently towards production is also considered. In other words, given the assumption of a stochastic resource stock, there is a potential team agency situation. Accordingly, remuneration systems based on incentive contracts offer an alternative rationale to the risk sharing contract. An interesting finding is that, for a given set of parameter values, remuneration system could include fixed wages independent of effort levels and revenue as well as no cost sharing. Along the same line, Platteau & Nugent (1992) reviewed empirical studies and found that fixed wages are observed among vessels that have difficulty attracting qualified captains. Also, flat wages are applied to the crew whose efforts can easily be observed and less directly affect the catch level.

A Model of Remuneration Choice in Fishery

Our model differs from the above mentioned models in the sense that it integrates both risk sharing and incentive into the analysis. The starting point of our theoretical model is the realization that effort level exerted by the crew is unverifiable due to uncontrollable factors (e.g., the fishing stock) in the production process. Accordingly, the principal-agent model (PA) is most appropriate in addressing the fisheries remuneration strategies.

To our knowledge the only paper that uses the PA approach is developed by MP (2006). According to principal-agent theory, as Acemoglu (1999) points out, contract is the mechanism designed to solve the trade-off between incentive and insurance. The latter is closely related to risk behavior of economic agents. Incentive and risk behavior are also crucial in fisheries. Accordingly, we focus on developing a model that puts a great emphasis on analyzing the integral relationship among incentive, effort, risk behavior as well as how this relationship leads to remuneration decision. Our model is more general than MP's in two aspects. First, MP only considers the case of risk neutral crew. Here, we consider all cases of risk behavior for both crew and owner. Second, we extend MP's model by treating effort level as a continuous rather than a binary variable.

Model Setup

Our model consists of two parts: a representative crew member and the vessel owner. The vessel owner is the principal who designs a contract with the crew. It is noted that we consider a representative crew rather than the whole crew to make the model tractable. This is different from the assumption that the crew acts as if it was taking decisions collectively. Fitzroy and Kraft (1987) give an example of a model where difference between collective and individual decision making is illuminated in a similar setting. If the effort level is observable, the contract consists of two components: (1) the effort level and (2) the corresponding wage of the crew. More realistically, effort level is not observed and only the latter is the contract element.

The crew's effort level is denoted by a continuous variable e and $e \in [e_L, e_H]$. Let $\pi(e,\varepsilon)$ be the profit which is a function of effort level and other unobserved factors. More specifically, following Mas-Colell, Whinton, and Green [MWG] (1995) we assume that the owner's profit relates to the crew's effort via the conditional probability density function $f(\pi|e)$. In other words, the owner's expected profit can be written as: $E(\pi \mid e) = \int \pi f(\pi \mid e) d\pi$. To make the model tractable, we consider the simple functional form: $\pi(e) = e + \varepsilon$, where ε represents all unobserved factors and is assumed to follow a normal distribution with mean of zero and variance of σ^2: $N(0, \sigma^2)$. It follows that $E(\pi \mid e) = \int \pi f(\pi \mid e) d\pi = e$ and $Var(\pi \mid e) = \sigma^2$. Note that the owner is not able to perfectly derive effort level based on the realized profit due to random factor ε.

As far as the crew's wage is concerned, we assume that the owner offers a linear payment scheme in the form of $w(\pi) = \alpha + \beta\pi$, where β is the share ratio of profit for the crew. Notice that $w = \alpha$ as $\beta=0$; thus α can be considered a fixed wage level offered by the owner to the crew. In what followed, we first consider conventional assumption of risk behavior among owner and crew.

Conventional risk assumptions: risk neutral owner and risk-averse crew

First, like MP (2006) we assume the owner is risk neutral given that he has more resource than the crew, and therefore can diversify investment easier. His expected utility takes the form: $E(U^{owner}) = E[(\pi \mid e) - w(\pi)]$. As for the crew, on the other hand, we follow conventional assumption that they are risk-averse. This assumption is considered standard in the literature, for instance, see Sutinen (1979); Plourde & Smith (1989); Matthiasson (1999); McConnell & Price (2006). More specifically, we assume that the crew's expected utility takes the following form: $E(U^{crew}) = E(w) - \varphi \operatorname{var}(w) - v(e)$, where E(w) is the expected wage; φ is a parameter representing how much risk-averse the crew is; var(w) is variance in the wage level denoted by σ^2; v(e) is the disutility function associated with the crew's effort, such as fatigue experienced by the crew from strenuous fishing activities. Following standard convention, v(e) is assumed to be strictly convex such that v'(e)>0 and v''(e)>0. The first assumption implies that the value of discomfort increases as effort increases. The second assumption implies that the value of discomfort increases at an increasing rate as effort increases.

Substituting the wage equation, w(π) = α + βπ, into the crew's expected utility expression, we have:

(1)

$$
\begin{aligned}
E(U^{crew}) &= E[\alpha + \beta(\pi \mid e) - \varphi \operatorname{var}(\alpha + \beta\pi \mid e) - v(e)] \\
&= \alpha + \beta E(\pi \mid e) - \varphi\beta^2 \operatorname{var}(\pi \mid e) - v(e) \\
&= \alpha + \beta E(e + \varepsilon) - \varphi\beta^2 \operatorname{var}(e + \varepsilon) - v(e) \\
&= \alpha + \beta e - \varphi\beta^2\sigma^2 - v(e)
\end{aligned}
$$

Given the above setup, the owner is assumed to face the following programming model:

$$(2) \qquad \underset{w(\pi)}{Max} E(U^{owner}) \equiv \int [(\pi - w(\pi)] f(\pi \mid e) d\pi = E(\pi \mid e) - E(w(\pi))$$

This is equivalent to:

$$(3) \qquad \underset{\alpha,\beta,e}{Max} E[U^{owner}] \equiv Max[E(\pi \mid e) - E(\alpha + \beta\pi \mid e)]$$

s.t.

Individual rationality condition: $EU^{crew} \geq \bar{U}$, where $\bar{U}$ is the reserved utility level of the crew.

Substituting EU^{crew} from (1), we have the following equivalent ndividual rationality condition:

$$(4) \qquad \alpha + \beta e - \varphi\beta^2\sigma^2 - v(e) \geq \bar{U}$$

Incentive compatibility condition:

$$(5) \qquad e = \arg\max[E(U^{crew})] \equiv \arg\max[\alpha + \beta e - \varphi\beta^2\sigma^2 - v(e)]$$

The incentive compatibility condition means that given the contract (β*, α*) offered by the owner, the crew would best respond by exerting the effort level of e*. The individual rationality (IR) expressed in equation (4) implies that the crew will accept the contract if and only if his utility gained from being employed by the owner is greater than his reserved utility. If it is not, he will choose an alternative job or choose to work at his home country as in the case of a foreign crew member.

Model solution

The first order condition from (4) above gives $\beta^*=v'(e^*)$. This result has a very nice economic interpretation, namely the marginal benefit of effort (β) is equal to its marginal cost (v'(e)). Also, given v''(e)>0, there is a one to one positive relation between β and e.

The higher the effort level is, the higher the profit and vice versa. Note also that the owner can always make the individual rationality condition (4) binding. Thus, we have:

(6) $$\alpha + \beta e - \varphi\beta^2\sigma^2 - v(e) = \bar{U}.$$

Substituting, $\beta^*=v'(e^*)$ and solve for α^* we have:

(7) $$\alpha^* = v(e^*) + \varphi v'(e^*)^2\sigma^2 - v'(e^*)e^* + \bar{U}$$

From the equation for α*, we see that the higher the reserved utility level is the higher the fixed portion of the crew's wage. In the context of vessels with foreign crew in Hawaii's longline fisheries, it is expected that α* is relatively small given that the foreign crew has a lower living standard at their home country.

Next, substituting α*, β* into (1) and solve the owner's expected utility maximization program with respect to e would yield the following.

(8)

$$\max_e E[U^{owner}] \equiv \max_e E[\pi \mid e - E(\alpha + \beta\pi)]$$

$$\equiv \max_e [E(\pi \mid e) - E\{v(e) + \varphi\sigma^2 v'(e)^2 - v'(e)e + \bar{U}\} - \beta E(\pi \mid e)]$$

$$\equiv \max_e [e - v(e) - \varphi\sigma^2 v'(e)^2 + v'(e)e - \bar{U} - v'(e)e]$$

$$\equiv \max_e [e - v(e) - \varphi\sigma^2 v'(e)^2 + v'(e)e - \bar{U}]$$

By the FOC with respect to e, we then have:

(9) $$1 - v'(e^*) - 2\varphi\sigma^2 v'(e^*)v''(e^*) = 0$$

Substituting $\beta^* = v'(e^*)$ and solving for β^*, we have:

(10) $$\beta^* = \frac{1}{1 + 2\varphi\sigma^2 v''(e^*)}$$

Equation (10) is the key finding of our theoretical model. From (10), we can see that $\beta^* \in (0,1]$ which is expected since β is the proportion of profit given to the crew. Also, the larger the variance in the profit level, σ^2, the smaller the share of profit will be given to the crew. This result is very relevant to fishery where the profit level by trip fluctuates a great deal due to a host of uncontrollable factors. In extreme cases, variation in the profit can be so big that the profit level $\pi = e + \varepsilon$ is largely determined by the unobserved factor ε. Accordingly, the owner finds it hard to tell which portion of the profit is determined by effort level. As a result, he would prefer the fixed wage system (choosing β=0). The risk parameter, φ, also plays an important role. The more risk-averse the crew, the lower will be his share of the profit. This finding is consistent with MP's (2006). In the context of Hawaii, an increasing number of crew is being hired from foreign countries. These fishermen consider fishing as the only source of income used to support them and remit to their home country. Therefore, they are very much averse to risk. This factor, in addition to large variation in profit, makes β even smaller. At some point, we can observe β=0 as the case of a fixed wage system.

It is also of great interest to look at the relationship between effort level and risk aversion. Eriksson, Teyssier, Villeval (2006) in their economic experiment on principal-agent model find out that more risk-averse participants exert less effort. From the FOC: $1 - v'(e^*) - 2\varphi\sigma^2 v'(e^*)v''(e^*) = 0$ and applying the implicit function theorem we have:

(11) $$\frac{de^*}{d\varphi} = -\frac{2\sigma^2 v'(e^*)v''(e^*)}{v''(e^*) + 2\varphi\sigma^2[v''(e^*)^2 + v'(e^*)v'''(e^*)]}$$

Thus, the sign of the relationship between effort and risk aversion depends on the sign of the third derivative of the effort disutility function v'''(e). As for v'''(e) > 0, e.g., the marginal disutility function of effort is convex, we observe a negative relationship between effort level and risk aversion. It could be that being risk-averse the agent is afraid that the cost of exerting more effort is greater than his increased share of the profit which depends on other uncontrollable factors.

General case of risk behavior for the owner and crew

We now consider the most general case of risk behavior for the owner and the crew. In this case, not only the crew but the owner also considers both his net income (π-w (π)) and variation in that income. Accordingly, his expected utility can be written as:

$$U^{owner} = \pi(e) - w(\pi) - \gamma \mathrm{var}[\pi(e) - w(\pi)] \tag{12}$$

where γ is the owner's level of risk aversion. Note that:

$$\mathrm{var}[\pi(e) - w(\pi)] = \mathrm{var}[(1-\beta)(\pi(e)) - \alpha] = \mathrm{var}[(1-\beta)(e - \varepsilon) - \alpha] = (1-\beta)^2\sigma^2$$

Thus, we have:

$$U^{owner} = \pi(e) - w(\pi) - \gamma(1-\beta)^2\sigma^2 \tag{13}$$

The individual rationality and incentive compatibility conditions are the same as those for the case of risk neutral owner. Following similar analysis, we can show that the owner faces the following programming model:

(14)

$$\underset{e}{\mathrm{Max}}\ E[U^{owner}] \equiv \mathrm{Max} E[e - v(e) - \sigma^2\{\varphi v'(e)^2 + \gamma(1\text{-}v'(e))^2\}]$$

By the FOC with respect to e, we have:

(15) $$1 - v'(e^*) - 2\sigma^2[\varphi v'(e^*)v''(e^*) - \gamma(1 - v'(e^*)v''(e^*)] = 0$$

Substituting $v'(e^*)=\beta^*$ and rearrange we have:

(16) $$1 + 2\gamma\sigma^2 v''(e^*) = \beta^*[1 + 2\varphi\sigma^2 v''(e^*) + 2\gamma\sigma^2 v''(e^*)]$$

Thus,

(17) $$\beta^* = \frac{1 + 2\gamma\sigma^2 v''(e^*)}{1 + 2\varphi\sigma^2 v''(e^*) + 2\gamma\sigma^2 v''(e^*)}$$

From (17), we have:

(18) $$\frac{\partial\beta}{\partial\gamma} = \frac{2\gamma\sigma^2 v''(e^*)}{[1 + 2\varphi\sigma^2 v''(e) + 2\gamma\sigma^2 v''(e^*)]^2} > 0\,.$$

In other words, the more risk-averse the owner is, the more willing he would be to increase the share of profit to the crew. The case in which the crew is risk neutral i.e., $\varphi = 0$ is also interesting. Here, we have $\beta^* = 1$. Thus, the owner's income is $\pi - \alpha - \beta\pi = -\alpha$; accordingly $\alpha < 0$. This will be equivalent to the situation where the owner leases the boat to the crew who pays the owner a fixed rent of α to use the boat. Table 2 summarizes the optimal crew shares for all possible combinations of risk behaviors of the crew and owner.

For the case of risk neutral crew, the main concern is the profit level. The owner optimal strategy is to lease the vessel to the crew and receive a fixed rent (MWG, 1995).

As for risk-averse owner, he is willing to pay a higher portion of the realized profit to the crew in exchange for risk sharing. Accordingly, the share of the profit for the crew is higher under the case of risk-averse owner than that of risk neutral owner. Also, given $v'(e^*) = \beta^*$, the more risk-averse the owner is, the higher β^* and the higher the optimal effort level e^*.

As far as the fixed portion of the crew's wage level α is concerned, from $\alpha^* = v(e^*) + \varphi v'(e^*)^2 \sigma^2 - v'(e^*)e^* + \bar{U}$, we have,

$$\frac{d\alpha^*}{de^*} = v''(e^*)[2\varphi v'(e^*) - e^*] \tag{19}$$

The interrelationship of α^* with β^* and e^* are thus less tractable unless we further assume some specific functional from of $v(e)$.

Empirical Model, Findings and Discussions

Before proceeding to the empirical exercise, we can infer *ceteris paribus* from the profit function: $\pi(e) = e + \varepsilon$ that the higher the effort level, the higher the profit level. However, the crew's effort is unobservable. Instead, we look at the relationship between the crew's share and profit level. One finding from the theoretical model is that there is an one-to-one positive relation between β^* and e^*: $\beta^* = v'(e^*)$. Accordingly, $e^* = g(\beta^*)$ where $g()$ is an inverse function of $v'()$. Substitute $e^*=g(\beta^*)$ into the profit function $\pi(e) = e + \varepsilon$, we have $\pi(\beta^*) = g(\beta^*) + \varepsilon$. This implies at the equilibrium $d\pi(\beta)/d\beta = g'(\beta^*) = 1/v''(\beta^*)$ which is greater than zero by assumption.

An Empirical Model

This section aims at empirically checking the theoretical prediction of the positive correlation between crew's share and the vessel's profit. We also investigate the related question if a share contract system generates higher economic returns than flat wage regime. In theory, the share parameter β is a continuous variable ranging from 0 to 1. According to the theoretical model, a higher β corresponds to higher economic returns. Due to unavailable detailed information regarding the crew's share in ex-post revenue, we consider two cases: the pure fixed wage (i.e. $\beta=0$) and the share contract (i.e. $0<\beta<1$) systems.

As far as the profit variable is concerned, since profit information is not available in our data, we use revenue as a proxy. Also, taking into account the multiple output feature of the longline fisheries, average trip revenue is used as the performance measure (the dependent variable) in this study. Average trip revenue is calculated by dividing the vessel's annual revenue into the number of fishing trips the vessel operated in 2004[3]. Fishing revenue is postulated to be affected by several factors (explanatory variables) that are known to have potential impacts on fishing revenue. One such variable is the remuneration method implemented.

To estimate the impact of share contracts on fishing revenue, one may consider using the following model:

[3] We realize that the average profit per trip would provide more informative measure of crew work effort intensity than the average revenue per trip. Unfortunately, we don't have information on profit. Thus, the use of revenue as a proxy for profit in our case is certainly less than desirable. However, we believe the use of revenue as a proxy can nevertheless shed some light on crew effort on economic returns in general.

$$(20) \qquad Y = X\beta + \delta I + \varepsilon$$

where Y is the fishing revenue; X is a vector of explanatory variables; and I is a binary variable indicating whether the vessel employs share contracts or flat wages (I=1 if the vessel uses share contracts, and I =0 if the vessel uses flat wages). However, this model may result in inconsistent estimates from the effect of share contracts on fishing revenue because employing share contracts may generate interaction effects with observed or unobserved vessel characteristics (Maddala, 1983; Kim et al., 1998). For instance, the level of technology of a vessel influences the vessel remuneration methods; yet similarly, the level of technology is correlated to revenue. If the decision to use share contracts is based on individual selection, there may exist selection biases[4] in that share contract vessels may have systematically different characteristics from flat wage vessels (Kim et al., 1998). Vessel characteristics may also have different impacts on revenue depending on the type of remuneration. The impact, for example, from hooks per set on revenue for vessels using share contracts may differ from vessels using flat wages.

To correct these problems, we invoke the switching regression model (Maddala, 1983), which simultaneously estimates the selection equation and two revenue regression

[4] In theory, the self-selectivity of remuneration regime may exist for both owners and crews. On the one hand, the owner offers compensation conditional on owner's attributes and expected revenues. On the other hand, the crew determines whether to accept the offer conditional on crew's attributes and expected revenues. In the context of Hawaii longline fishery, majority of crews are foreigners whose main objective is to be employed by a vessel onwer, regardless of remuneration practice, to have salary and send it back to family at home. Accordingly, we can assume that the remuneration choice endogeneity refers to owner's behavior only.

equations for share contract and fixed wage vessels. The empirical model follows closely the formulation of Lokshin and Sajaia (2005). To consider a model that describes choosing remuneration systems with two regression equations, we define a criterion function I determining whether the vessel employs share contracts or not:

(21)

$$
\begin{aligned}
I_i &= 1 \quad \text{if} \quad \gamma' Z_i + u_i > 0 \\
I_i &= 0 \quad \text{if} \quad \gamma' Z_i + u_i < 0
\end{aligned}
$$

where $I_i = 1$ if vessel i uses share contracts, and $I_i = 0$ if vessel i uses fixed wages. Z_i is a vector of variables that influences vessels' contractual choice; Z_i includes vessel's current appraised value, the number of hooks used per fishing set, and a binary variable indicating the ease with which the vessel can find local crew. It is expected that the higher the vessel's current appraised value and the higher the number of hooks per set, the less the vessel's revenue depends on the crew, the more likely the vessel's owner will apply fixed wage. Also, given that local crew may be less risk-averse than foreign crew, the easier it is for the owner to find local crew, the more likely he will apply share contract.

The revenue regression equations for share contract and flat wage vessels then can be defined as:

$$(22) \qquad y_{1i} = \beta_1' X_i + \varepsilon_{1i} \qquad \text{if} \quad I_i = 1$$

$$(23) \qquad y_{2i} = \beta_2' X_i + \varepsilon_{2i} \qquad \text{if} \quad I_i = 0$$

where y_{1i} and y_{2i} are the average trip revenue for share contract and flat wage vessels respectively. X_i is a vector of explanatory variables thought to affect vessel revenue, including the current appraised vessel value and the number of hooks used per fishing set[5]. These two variables represent the technological status of the vessel, thus, are expected to have positive impact on the vessel revenue.

Assume also that u_i, ε_{1i}, and ε_{2i} follow a trivariate normal distribution with zero means and the covariance matrix:

$$\Omega = \begin{bmatrix} \sigma_u^2 & \sigma_{u1} & \sigma_{u2} \\ \sigma_{u1} & \sigma_1^2 & \\ \sigma_{u2} & & \sigma_2^2 \end{bmatrix}$$

where σ_u^2, σ_1^2, σ_2^2 are variance of the error terms in the selection equation (21), the share contract equation (22), and flat wage equation (23) respectively; σ_{21} and σ_{31} are the covariance between the error term in the selection equation (21) with the error terms in equation (22) and equation (23) respectively.

Given these assumptions of the error terms, the logarithmic likelihood function for equations (22) and (23) can be expressed as:

$$\text{(24)} \qquad \ln L = \sum_{i=1} \{I_i[\ln(F(\eta_{1i}) + \ln(f(\varepsilon_{1i}/\sigma_1)/\sigma_1) + (1-I_i)[\ln(1-F(\eta_{2i})) + \ln(f(\varepsilon_{2i}/\sigma_2)/\sigma_2)]\}$$

F() and f() are the cumulative distribution and the distribution function respectively. η_{ji} is defined as follows:

[5] In the revenue regression, we include capital and labor as inputs. We notice that, besides these variables, fish stock and captains' experience are important determinants. As for fish stock, we don't have information in the data. We have also included the captain's experience in our model estimations; however, the findings were not significantly different from those reported in this paper. Therefore, we use the current model because it is simpler but give the same results.

(25) $$\eta_{ji} = \frac{(\gamma Z_i + \rho_j \varepsilon_{ji} / \sigma_j)}{\sqrt{1-\rho_j^2}} \qquad j=1,2$$

where ρ_1, ρ_2 are the correlation coefficient of u with ε_1 and ε_2 respectively.

We are particularly interested in the potential revenue gain/loss in the event a vessel uses an alternative method of remuneration. We expect that the empirical results should yield the differences in vessel revenue when share contract vessels switch to a flat wage system instead, and vice versa. To verify our expectation, the following conditional expectations are constructed:

The conditional expectation of revenue of a vessel using share contract is:

(26) $$E(y_{1i} \mid I_i = 1, x_{1i}) = x_{1i}\beta_1 + \sigma_1\rho_1 f(\gamma Z_i) / F(\gamma Z_i)$$

The conditional expectation of revenue of a share contract vessel if it applied flat wage is:

(27) $$E(y_{0i} \mid I_i = 1, x_{1i}) = x_{1i}\beta_2 + \frac{\sigma_2\rho_2 f(\gamma Z_i)}{F(\gamma Z_i)}$$

The expected potential gain/loss of a share contract vessel if it applied flat wage will be:

(28) $$E(y_{0i} \mid I_i = 1, x_{1i}) - E(y_{1i} \mid I_i = 1, x_{1i})$$

Similarly, the conditionally expected revenue of a flat wage vessel if it applied share contract is:

(29) $$E(y_{1i} \mid I_i = 0, x_{2i}) = x_{2i}\beta_1 - \frac{\sigma_1\rho_1 f(\gamma Z_i)}{1 - F(\gamma Z_i)}$$

The conditional expectation of revenue of a vessel using flat wage is:

(30) $$E(y_{0i} \mid I_i = 0, x_{2i}) = x_{2i}\beta_2 - \frac{\sigma_2\rho_2 f(\gamma Z_i)}{1 - F(\gamma Z_i)}$$

The expected potential gain/loss of a flat wage vessel by applying share contract instead will be:

(31) $$E(y_{1i} \mid I_i = 0, x_{2i}) - E(y_{0i} \mid I_i = 0, x_{2i})$$

Data

Data collected and used for this study from the 2004 Hawaii-based Longline Technology Survey (HLTS) provides baseline fishing technology and some economic information on the Hawaii-based domestic longline fleet. The unit of survey is an individual longline vessel. There are 86 surveyed vessels. Traditionally, the Hawaii longline fisheries include both tuna and swordfish. However, the HLTS focused only on the tuna fishery, due to the swordfish fishery closure in March 2004. The survey questionnaire included two main sections. The first section provided key information on the number of crew, remuneration method, and fishing experience of the captain. The second section focused on the technology onboard the vessel: a list of all electronic equipment (e.g., satellite communication, computers, etc.), dates of when each piece of technological equipment was adopted, and the purchase price of each piece of equipment. The appraised current vessel value was used as proxy for the overall technological status of the vessel. It is noted that the appraised value might not be a good indicator of technology because it accounts for depreciation. For instance, if there are two vessels with exactly the same equipments but with different vessel age, their appraised values may differ but their technology are the same. We realized this fact and run econometric models controlling for the vessel's age; however, the findings were not significantly different from those reported in this paper.

Because the HLTS did not survey vessel revenue information, two other sources of data were employed in this study. The first data set, from the Hawaii Division of Aquatic Resources (HDAR), provided detailed information in 2004 on vessel's catch, by species, with its corresponding auction price. Based on this information the vessel's annual revenue was estimated as well as the total number of fishing trips taken during that year. The second data set from logbook data, provided by the National Marine Fisheries Services, contained detailed information on the quantity of fish (by species) landed and kept per vessel. These three datasets were linked using vessel names and permit numbers. We use the combined data for the empirical exercise.

Table 3 presents three key relationships between vessel characteristics and remuneration regime found in the combined data. First, if the vessel crew size is larger than 5, there is a high probability of vessels to use a fixed wage regime. However, vessels using hired captains rather than having owner operators have a higher probability of using a share contract regime. Third, if it is easy to find the crew, there is high probability that vessels will employ share contract.

Model Specification

There are two important variables used in the analysis: remuneration choice and average revenue per trip. The remuneration choice (binary) variable is 1 if there is at least one crew hired by share contract in addition to the captain, and 0 if otherwise.[6] These two variables form the foundation for the estimation procedures. Appendix 1 briefly defines all the variables used in the empirical model.

As part of the switching regression procedure, a probit model is used to investigate the determinants of employing share contracts in the Hawaii longline fisheries. There are two sets of independent variables. The first set includes all explanatory variables in the revenue regression equations. Such inclusion takes into account the fact that fishing revenue also has an impact on the owner's decision to use share contracts. Owners will be more likely to employ share contracts if it results in higher revenue than flat wage. Hence, factors that have an impact on revenue may also have correspondingly similar impacts on the remuneration choice. Also, as pointed out by Wooldridge (2004:562), "inclusion of the second stage's variables in the first stage is not very costly while incorrect exclusion may lead to inconsistent estimations." The second

[6] In reality, remuneration system used among Hawaii longline fishing boats is a bit more complex than what we are assuming here. Some vessels had split crews such as a Vietnamese captain, first mate and cook (who all fished too) and a crew of foreign workers (e.g. Filipinos, Micronesians, etc). The captain, first mate, and cook were paid on share contract and the foreign crew by fixed wage.

set of the independent variables in the share contract equation aims at satisfying the identification condition. Non-linearity is not sufficient to meet the identification condition; rather, additional identifying variables are added in the first equation. These variables are not included in the revenue equations. Bound, Jaeger, and Baker (1995) suggests that using weak instruments are problematic since the potential bias does not disappear even in a large sample. Given the small sample size of our data, it is even more crucial to choose good instruments. We also follow Wooldridge (2004:104) by not using any interaction term to limit the number of over-identifying restrictions. In particular, we include three instrumental variables. The first one is a binary variable representing the ease with which owners find crew. The second instrument is the ethnicity of the vessel owner. The third instrument is a binary variable indicating whether the captain is also the vessel owner. These variables do not significantly impact vessel revenue but rather have a significant impact on the owner's decision to use share contracts.

In addition to share contracts, other potential determinants of fishing revenue were integrated into the model. We make use of the vessel's appraised current value as a proxy for the overall technological status of the vessel. Number of fishing hooks used per set was used as a proxy to measure the utilization of a vessel's potential fishing capacity. The more hooks used per set, the more a vessel could utilize its fishing capacity potential. Number of crew served as a proxy for vessel's human resources. The size of the crew is expected to have a positive correlation with the vessel revenue.

Table 4 shows comparison of descriptive statistics between share contract and fixed wage vessels. As can be seen from Table 4, fixed wage vessels outperform share contract vessels in terms of revenue. It is also noted that share contract vessels have higher appraised current value whereas flat wage vessels utilize more hooks per set. This contrast highlights different strategies to improve total revenue. Share contracts vessels focus on technological investments, whereas flat wage vessels emphasize increasing the number of hooks used per set. These differences are, however, insignificant. The significant difference that we are most interested in is the ease in finding local crew. As expected, it is much easier for share contract vessels to find local crew than it is for fixed wage vessels.

Main Empirical Results

Table 5 presents the determinants of share contract. The key factor in determining remuneration regimes is the ease of finding a local crew. The easier it is for the owner to find a local crew, the more likely he prefers using share contracts. This finding reflects present circumstances within the Hawaii longline fisheries. As owners experience a shortage in the supply of local fishermen, owners must depend on a third party to find foreign crew. As implied by the theoretical model, it might be in the owner's interest to use fixed wages given high level of risk aversion among foreign crew.

There are also two other variables that show significant impacts on using share contracts. Owner operated vessels are more likely to use flat wages because the owners can supervise their crew during the fishing trip. Vessels with larger crews also prefer flat wages to share contracts possibly because of the trade-off between the quality and quantity of the crew. It is likely that vessel owners of large crew do not place much emphasis on the marginal productivity of each crew member which is hard to identify. Meanwhile, owners with small number of crew may believe in the quality of crew and thus use share contract as a mechanism to increase marginal productivity of each crew.

The effect of vessel's characteristics on its fishing revenue is different among share contract and flat wage vessels (Table 6). The technological status of the vessel has a significant impact on fishing revenue among flat wage vessels, though this is insignificant for share contract vessels. Thus, technological investment may help improve productivity of flat wage vessels while this may have little impact on vessels using share contracts. Notice in Table 4 that fixed wage vessels have smaller current vessel values; therefore, a lower return on technology of share contract vessels can be attributed to diminishing return on investment. The effect of the number of hooks used per set on fishing revenue is consistently significant in these two groups of vessels: both remuneration strategies produce higher economic returns when there are more hooks per set. Interestingly, the estimated coefficient for the share contract equation is greater than that for the flat wage equation, which implies that share contract vessels may make more efficient use of hooks than flat wage vessels. As far as the effect of the crew size on revenue is concerned, the more crew members there are, higher revenue is realized. However, this effect is significant only among the share contract vessels. This result is consistent with what we discussed above regarding the trade-off between quality and quantity of crew. It is likely that share contract vessels place more emphasis on the quality of crew; therefore, an increase in the number of crew among share contract vessels leads to more significant improvement in revenue than among flat wage vessels.

The estimated correlation coefficients ρ_1 and ρ_2 between the error term in the selection equation and the error terms in the share contract and flat wage regression equations reveal any selection bias in the share contract decision. ρ_1 is statistically significant; but ρ_2, though it is negative, is insignificant. Given both ρ_1 and ρ_2 are negative, one can infer that the flat wage vessels may have an "absolute advantage." That is, flat wage vessels would have above average performance whether they chose to use share contract or not. In this case, share contract vessels have below average performance whether they chose to use share contract or not. In other words, the flat wage vessels are generally better fishers.

Having estimated the parameters of the switching regression models, we can calculate the expected gains and losses from counterfactual revenue differences [equation 28 and 31]. These results will show whether it is economically beneficial for the share contract vessels to employ flat wages and conversely whether it is better for the flat wage vessels to employ share contracts.

Table 7 presents the differences between the expected revenue of the counterfactual and expected revenue of the actual. The counterfactual is defined as the expected revenue a share contract (flat wage) vessel would have generated if it had used flat wages (share contracts). A key finding is that flat wage vessels would markedly increase their revenue margins if they had applied share contracts. This finding has significant implications for the Hawaii longline fisheries as recently more share contract vessels have changed to using flat wages. One of the reasons for this change is that foreign crew have recently been the main source of fishermen in Hawaii. Foreign crew may be more risk-averse than local crew because of their dependence on fishing as the only source of income. As implied by the theoretical model, it is optimal for the owner to use flat wage the case of very risk-averse crew. However, not all foreign crew are very risk-averse, some of them may even be risk neutral or risk preferred. It might be more beneficial for the owner to use share contract under such circumstances. Put it differently, a more flexible remuneration system may be better than a pure fixed wage regime. This finding is consistent with that by Eriksson, Teyssier, Villeval (2006) who show that workers would exert more effort if they had the flexibility of choosing the remuneration practice in accordance with their risk preference.

Conclusions

This paper attempts to systematically answer the question: "why share contract regime is the optimal form of remuneration in the fisheries sector?" By focusing on the Hawaii longline fisheries, where flat wage has recently become the preferred mode of remuneration, we have a strong case to test this theoretical prediction. Using the principal-agent approach, we develop a simple and comprehensive model that take into account the role of both incentive and risk behavior to explain the underlying mechanism of remuneration choice in fisheries. Our model suggests that there is a trade-off between incentive and risk aversion. The more risk-averse the crew is, less incentive will be brought about by the contract. Accordingly, it might be optimal for the owner to use fixed wage under certain circumstance. As in the case of Hawaii's longline fisheries, one of the primary reasons for the substitution of share contract for fixed wage has been the lack of local crew members keeping longlining as their primary occupation. As a result, the vessel owner is relegated to hire foreign crew who are more risk-averse than local crew. The high level of risk aversion among foreign crews is probably one of the reasons for the recent observed move to fixed wage in remuneration practice.

Empirically, this is one of the first studies investigating the impact of share contracts on fishing productivity. The counterfactual simulations indicated that vessels employing flat wages would produce higher fishing revenues if they adapt a more flexible remuneration system that best fit the crew's risk behavior rather than a pure fixed wage regime. More specifically, it may be better for the Hawaii longline fleet if foreign crew has the possibility of choosing remuneration scheme that fits their risk behavior rather than letting remuneration to be solely determined by the owner.

Our model shows that risk behavior of the crew and owner plays an important role in deciding how large the optimal revenue sharing parameter β should be. The paper could have more profound findings if we had data on the risk preference. A promising extension of the study is to conduct an experiment on risk preferences among crew and owners in Hawaii's longline fishery. We then can combine experimental data with data used here.

There are several limitations of this study. First, the theoretical model investigates the relationship between risk aversion of the owner and crew and choice of remuneration. However, the current dataset does not contain measures of "risk aversion" for either party. Conducting a field experiment on risk preferences of Hawaii longline fishermen would be a worthwhile extension. Second, we do not have the data for specific values of the share parameter β; thus, instead of treating β as a continuous variable, we simply treat it as a binary variable. The theoretical model predicts that the greater percentage of the crew share, the higher the vessel revenue will be. It will be interesting to see how a change in the shared revenue portions impact revenue margins.

There are also a number of interesting facets of remuneration in Hawaii longline fisheries that can be grounds for future investigation. First, foreign crew and local crew may consist of different labor qualities. These differences in quality may have an impact on an owner's decision regarding remuneration strategies. An owner, for example, may be more inclined to use share contracts with high quality labor. Further studies of the determinants that influence labor quality can be a fruitful area for future research. Second, the Hawaii longline fisheries consist of three ethnicities of vessel owners, which imply different decision making behaviors. Asian owners, for example, might prefer share contracts that promote cooperation. Investigating the effect of ethnicity on remuneration choice is a matter of great relevance. Lastly, owners with a fleet of vessels may prefer to apply the same kind of remuneration on all of his boats. Given that it is not uncommon for an owner to possess multiple boats in the Hawaii longline fisheries, another potential extension of the paper would explore how this feature influences the use of a particular remuneration strategy.

References

Acemoglu, D. 1999 *Lecture Notes for Graduate Labor Economics, 14.661*, MIT.

Azabou, M; Bouzaiane, L; and Nugent, B.J. 1989. Contractual Choice in Tunisian Fishing. *The New Institutional Economics and Development,* North Holland.

Bound, J; Jaeger, A.D; and Baker, **M.R.** 1995. "Problems with Instrumental Variables Estimation When the Correlation Between the Instruments and the Endogenous Explanatory Variable is Weak". *Journal of the American Statistical Association*, 90(430): 443-450.

Eriksson, T; Teyssier, S; and Villeval, M.C. 2006 "Self-Selection and the Efficiency of Tournaments". *IZA Discussion Paper No. 1983.*

FitzRoy, F. R and Kraft, K. 1987. "Cooperation, Profitability and Profit Sharing." *Quarterly Journal of Economics* 102: 23-35.

Key, N; and McBride, W. 2003. Production Contracts and Productivity in the U.S. Hog Sector. *American Journal of Agricultural Economics*, 85(1): 121-133.

Kim, S. Y; Nayga, M.R; Capps, O; and Tepper, B. 1998. *Consumer Label Use and Diet Quality: An Endogenous Switching Regression Analysis*. Invited Paper presented at the Food and Agricultural Marketing Consortium Conference on New Economic Approaches to Consumer Welfare and Nutrition, Alexandria, Virginia, January 14-15, 1999.

Lokshin, M; and Sajaia, Z. 2005. *Maximum-likelihood estimation of endogenous switching regression models*. The World Bank, US.

Maddala, G.S. 1983. *Limited-dependent and Qualitative Variables in Econometrics*, Cambridge University Press.

Mas-Colell, A; Whinston, M; and Green, J. 1995, *Microeconomic Theory*, Oxford University Press.

Matthiasson, T. 1997. Fixed Wage or Share: Contingent Contract Renewal and Skipper Motivation, Institute for Economic Studies, University of Iceland.

Matthiasson, T. 1999. Cost Sharing and Catch Sharing. *Journal of Development Economics, 58*(1): 25-44.

McConnell, E. K; and Price, . 2006. "The Lay System in Commercial Fisheries: Origin and Implications". *Journal of Environmental Economics and Management*. 51(3): 295-307.

Platteau, J.P; and Nugent, J. 1992. Share Contracts and their Rationale: Lessons from Marine Fishing. *The Journal of Development Studies,* 28(3): 386-422.

O'Malley, J.M; and Pooley, **S.G**. 2003. *Economic and Operational Characteristics of the Hawaii-Based Longline Fleet in 2000*.

Pradhan, N.C; and Leung, **P.S.** 2004. Modeling trip choice behavior of the longline fishers in Hawaii *Fisheries Research* 68:209-224.

Plourde, C; and Smith, J.B. 1989. Crop Sharing in the Fishery and Industry Equilibrium. *Marine Resources Economics*..6: 179-193.

Sutinen, J.G. 1979 "Fishermen's Remuneration Systems and Implications for Fisheries Development." *Scottish Journal of Political Economy*,. 26(2): 147-162.

Wooldridge, J.M. 2004. *Introductory Econometrics: A Modern Approach*, 2nd edition, The MIT Press, Cambridge, Massachusetts, London, England.

Wooldridge, J.M. 2004. *Econometric Analysis of Cross Section and Panel Data*. The MIT Press, Cambridge, Massachusetts, London, England.

Table 1. Comparative Vulnerability of Different Remuneration Systems

Type of Vulnerability	Fixed Wage	Share Contract
Labor Shirking	Serious	Moderate
Asset management	Serious	Moderate
Output Underreporting	Serious	Moderate
Input Over-reporting	Serious	Moderate
Quality Shirking	Slight	Slight
Production Risk	Borne by Owner	Shared
Price Risk	Borne by owner	Shared

Source: Adapted from Platteau and Nugent (1992)

Table 2: Optimal Values of β under Different Risk Behavior Scenarios

	Risk-averse owner	Risk neutral owner
Risk-averse crew	$0<\beta^{*}oc<1$	$0<\beta^{*}oc <\beta^{*}c<1$
Risk neutral crew	$\beta^{*}= 1$	$\beta^{*} =1$

Note: $\beta^{*}oc$ corresponds to the case in which both crew and owner are risk-averse.
□*c corresponds to the case in which only crew is risk-averse.

Table 3. Main Vessel Characteristics by Remuneration Regime

Vessel Characteristics	Share Contract (%)	Flat Wage (%)
Number of crew		
Equal to 5	47.9	52.1
Less than 5	87.5	12.5
Greater than 5	45.4	54.6
Owner operator		
Yes	48.7	51.3
No	59.2	40.8
Difficulty in finding a crew		
Very difficult	45.4	54.6
Not much	74.0	26.0
Number of Vessels	55	45

Table 4. Mean Comparisons by Main Characteristics of Vessels

	Total sample (1)	Share contract (2)	Flat wage (3)	p-values(+) (2)-(3)
Vessel's trip revenue ($)	31,295	30,714	31,920	0.73
Vessel's appraised current value ($)	428,116	456,316	393,548	0.13
Ethnicity	1.8	1.7	1.9	
Time working together (years)	0.5	0.5	0.5	0.46
Hooks per set	1945	1924	1968	0.72
Easy to find local crew (Easy=1)	0.36	0.47	0.23	0.01***
Number of crew	5.12	4.9	5.3	0.005***

(+) Based on a one-tailed t-test

** indicates significance at 5% level, *** indicates significance at 1% level.

Table 1.5: Determinants of Share Contract

Variable	Coefficient	t value	p>|t|
Vessel's Current Value ($)	0.0007	0.71	0.47
Hooks per fishing set (number)	-0.0004	-0.56	0.58
Easy to Find Crew (1=yes; 0=no)	0.64	2.68^{***}	0.00
Owner's ethnicity	0.17	0.54	0.59
(1=Caucasian, 2=Korean,			
3=Vietnamese)	-0.72	-1.97^{**}	0.05
Owner operated (1=yes; 0=no)	-0.81	-2.40^{***}	0.01
Number of crew	64		
Number of estimated observation			

Note: ** indicates significance at 5% level; *** indicates significance at 1% level.

Table 6. Parameter Estimates of the Revenue Equations

Variable	Share Contract		Flat Wage	
	Coefficient	p>|t|	Coefficient	p>|t|
Vessel's Current Value	2.49	0.42	19.08^{***}	0.00
Hooks per fishing set	14.07	0.00	8.33^{***}	0.01
Number of Crew	4729	0.03	578	0.69
Number of observation = 64				
ρ_1	-0.64^{**}			0.03
ρ_2	-0.17			0.77

Note: ** indicates significance at 5% level; ** indicates significance at 1% level.

Table 7. Counterfactual versus Expected Revenue

Revenue	Difference between counterfactual and expected actual revenue	p-value
Share contract vessels	734	0.28
Flat wage vessels	7314***	0.00

Note: *** indicates significance at 1% level.

APPENDIX 1

A Brief Definition of Variables in the Empirical Model

Variable	Definition
Share contract	A binary variable whose value is 1 if the vessel applies share contracts and 0 if it applies flat wages
Vessel revenue	The average revenue of vessel per trip
Vessel current appraised value	The estimated value of the vessel
Ethnicity	Ethnic traits of vessel owner 1 represents Caucasian, 2 represents Korean American, and 3 represents Vietnamese American
Time crew working together	Years which the same crew spent working together
Hooks per set	The average number of hooks used per fishing set.
Ease to find crew members	How easy is it to find a local fisherman? 1. Easy 0. Otherwise