FISHERY MANAGEMENT IN A HOUSEHOLD ECONOMY: WILL INDIVIDUAL TRANSFERABLE QUOTAS SYSTEM WORK?

by

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Individual transferable quotas system is widely regarded as the best fishery management regime. The literature, however, has ignored the consequence of this managerial system when implemented in an economy where fishermen are both producer and consumer of its own harvest. This article analyzes the behavior of fishing households based on the household model when individual transferable quota system is introduced under missing labor market. It is shown that the individual transferable quotas system could adversely redistribute the quotas through quotas trade and thus cause social inefficiency.

Key Words: fishery management, household model, individual transferable quotas, market imperfection, missing labor market

Introduction

Individual transferable quota is a property rights-based fishery management regime that have been implemented in many fisheries in several countries, such as New Zealand, Australia, Canada, Iceland, and USA. The structure of the regime is much analogous to that of pollution permit system: it limits the total harvest in the form of total allowable catch (TAC), and a share of TAC is allocated to each harvester as a quota. Quotas can be traded among harvesters in the quota market. Theoretically, the price of quota will reflect all or some of externalities caused by the common-pool nature of fishery resources and thus are internalized by harvesters.

There are widespread literatures on individual transferable quotas, generally regarding it as the best management regime among others in terms of efficiency, i.e., maximizing the net return from the fishery (Arnason). There are literatures discussing the issues which individual transferable quotas might not be efficient, such as the case of high-grading (Anderson) and production externalities (Boyce). Nevertheless, it is often argued that although the individual transferable quotas do not lead to the first-best outcome, it is the best management regime in the sense that it results in a superior outcome among others available and/or currently practiced regimes (Grafton).

These literatures, however, treat fishery as an industry and fishermen and/or vessel owners as merely a producer of the commodity. What seems to be missing in the literature is the analysis of the impact of individual transferable quotas when fishermen are not just a producer but also a consumer of his own harvest. In developing countries, many fishermen are both producer and consumer of his own harvest. The issues of over-exploitation of fish stock are also prevalent in these countries (Asian Development Bank), indicating clearly that some regime of fishery management is necessary. The question is: will individual transferable quotas work in fisheries in such developing countries, as it does in developed countries?

The analyses of a household, i.e., an economic entity that is both a producer and consumer of its own production, can be found in the literature of agricultural development economics. There are both theoretical grounds and empirical evidences where households behave differently from being a pure producer (Finkelshtain and Chalfant, , Singh, Squire and Strauss). Furthermore, in the presence of imperfect markets, which is prevalent in developing countries, it is shown that the behavior of a peasant household is different from what one might expect as rational (de Janvry, Fafchamps and Sadoulet).

This article analyzes the behavior of fishing households based on the household model introduced by Singh, Squire and Strauss (1986). First analysis is under the assumption that all markets are perfect. In this case the individual transferable quotas system yield a first-best outcome: it will induce a redistribution of quota in such a way that more productive household will acquire additional quota while less productive household will sell some of its initially allocated quota. Second analysis considers the existence of labor market imperfection. An important result shown in this case is that there exists a possibility that the individual transferable quotas system will adversely redistribute the quotas: transfer from more productive household to less productive household. In such case the transferability of quotas could potentially cause negative effects on social welfare.

There are issues, although intellectually interesting, which this article will not cover. First, market imperfection is not limited to labor market; however this article will not consider other types of market imperfection. Other forms of market imperfection include missing credit market, insurance market, other marketed goods, and so on. Second, uncertainty and risk are not considered in the analyses. These aspects are left for future research.

The organization of this article is as follows. In the next section, the household model under perfect markets assumption is analyzed. The results derived in this section will serve as a benchmark. Next section analyzes the consequence of individual transferable quotas under missing labor market. Last section is the conclusion.

Model

Three goods are considered in the household model. One is the fish, which a household harvests as production activity and also consumes. Second good is leisure. Each household is assumed to have a certain endowment of time, $\overline{T}_i$, which it allocated between leisure and labor. Third good is other marketed goods, which essentially includes everything else that a household consumes other than fish and leisure. Markets for these goods are assumed to be perfect.

Other assumptions are as follows. Firstly, utility function of each household is concave in all goods, twice differentiable, and satisfies local non-satiation. Secondly, production (or harvest) is assumed to be a function of two inputs: labor and capital. The level of capital input, however, is assumed to be fixed[1]. I assume production function to be concave in inputs and twice differentiable. Thirdly, this article will not get into how the initial allocation of quotas should be done, but rather treats the initial allocation as given. It is also assumed that initial quotas were granted at no cost to each fishing household.

Perfect market

In this basic model all markets exist and are perfect. All prices are fixed and exogenous for all households. The maximization problem of a household *i* can be written as:

$$\max_{x_f^i, x_m^i, x_l^i, L_i, q_i} \quad u_i\left(x_f^i, x_m^i, x_l^i\right)$$

subject to:

$$p_f x_f^i + p_m x_m^i \leq \pi_i$$

$$\pi_i = p_f h_i\left(L_i, \overline{K}_i\right) - w\left(L_i - F_i\right) - s\left[q_i - \overline{q}_i\right]$$

$$h_i(\cdot) \leq q_i\,, \quad F_i \equiv \overline{T}_i - x_l^i$$

Subscripts f, m, and l denotes fish, other market goods that households do not produce, and leisure, respectively. x_j^i is the consumption of household *i* of good *j*, and p_j is the market price of good *j*. Other prices involved are wage rate and quota price, which are denoted as w and s, respectively. h_i is the harvest of household *i* as a function of labor (L_i) and fixed capital ($\overline{K}_i$). F_i is the household labor supply and hence the term $L_i - F_i$ defines hired labor. $\overline{T}_i$ is time endowment defined as average on-activity hours per person times the number of working household members. $\overline{q}_i$ is the initial quotas allocated to a household *i* (exogenous variable), and q_i is the amount of quotas a household *i* possesses after the trade (choice variable). π_i is the profit of a household *i*.

Lagrangian can be written as:

(1) $$\Omega = u_i\left(x_f^i, x_m^i, x_l^i\right) - \lambda_i\left[p_f x_f^i + p_m x_m^i + w x_l^i - p_f h_i\left(L_i, \overline{K}_i\right) + wL_i - w\overline{T}_i + s\left(q_i - \overline{q}_i\right)\right] - \mu_i\left[h_i\left(L_i, \overline{K}_i\right) - q_i\right]$$

Kuhn-Tucker first order necessary conditions are:

$$(2) \qquad x_f^i: \qquad \frac{\partial u_i}{\partial x_f^i} - \lambda_i p_f = 0$$

$$(3) \qquad x_l^i: \qquad \frac{\partial u_i}{\partial x_l^i} - \lambda_i w = 0$$

$$(4) \qquad L_i: \qquad \frac{\partial h_i}{\partial L_i}\left(p_f - \frac{\mu_i}{\lambda_i}\right) = w$$

$$(5) \qquad q_i: \qquad s = \frac{\mu_i}{\lambda_i}$$

$$(6) \qquad \mu_i: \qquad h_i\left(L_i, \overline{K}_i\right) - q_i \le 0, \qquad \mu_i\left[h_i\left(L_i, \overline{K}_i\right) - q_i\right] = 0$$

Following proposition can be derived from these FOCs, which will be useful in our later analyses.

Proposition: If total harvest quota constraint is binding and quota market price is exogenous, then at optimum each household will equate its harvest level and amount of quota it possesses.

Proof: First consider the case where each household does not equate its harvest level and amount of quota it possesses at optimum, i.e. $h_i^* \ne q_i$ for all *i*. From equation (6), this implies that $\mu_i = 0$, which then leads to $s = 0$, i.e. quota price is zero, from equation (5). This will occur if the total quota constraint is not bonding, i.e. $\overline{Q} \equiv \sum_i \overline{q}_i \ge \sum_i \widetilde{h}_i$, where $\widetilde{h}_i$ is the optimal harvest level of household *i* before the introduction of quotas[2]. Now consider the case where the total quota constraint is binding. If this is the case then $s > 0$, and from equation (5) $\mu_i > 0$ for all *i* must hold[3], and then equation (6) implies that $h_i^* = q_i$ for all *i*.

Notice that the required equality is $h_i^* = q_i$ and not $h_i^* = \overline{q}_i$. The process of decision-making would be to determine the harvest level first by observing exogenous market prices and then adjust its quota holdings via quota trade.

In this basic model, the level of harvest will be determined through optimal choice of labor input. From equations (4) and (5), one can derive:

(7) $$\frac{\partial h_i}{\partial L_i} = \frac{w}{p_f - s}.$$

Assuming $p_f > s$ [4], equation (7) determines the optimal level of labor input. Optimal harvest level, $h_i^* = h_i\left(L_i^*, \overline{K}_i\right)$, is then determined.

With h_i^* determined, we can now turn to the quota market. Recall that at optimum the condition $h_i^* = q_i$ must hold. The decision rule is if $h_i^* > \overline{q}_i$ then purchase additional quota from the market, and if $h_i^* < \overline{q}_i$ then sell excess quota to the market.

Following two-agent example will illustrate how individual transferable quotas system works. Suppose there are two households A and B. Household A has lower productivity of fishing than B, i.e. for any given amount of labor $\overline{L}$, $\frac{\partial h_A}{\partial \overline{L}} < \frac{\partial h_B}{\partial \overline{L}}$. Assume further that initial quotas are distributed equally ($\overline{q}_A = \overline{q}_B$), both have same capital inputs ($\overline{K}_A = \overline{K}_B \equiv \overline{K}$), and household A has more time endowment than B ($\overline{T}_A > \overline{T}_B$) [5]. Otherwise two households are identical.

Since prices are exogenous and fixed, the right-hand side of equation (7) is predetermined, and the left-hand side of the equation is then determined independently from the current amount of quotas in possession. Therefore, in general $h_i^* \neq \overline{q}_i$ *ex ante*. Furthermore, since all prices are fixed and faced by all households, at optimum $\frac{\partial h_A^*}{\partial L_A} = \frac{\partial h_B^*}{\partial L_B}$ must hold, which implies $L_A < L_B$ and thus $h_A^* < h_B^*$.

Suppose initial allocation was such that household A has more than its optimal level and household B has less than its optimum; i.e. $h_A^* < \overline{q}_A$ and $h_B^* > \overline{q}_B$. If there was no quota market household A is wasting its excess quotas that have some positive value and household B is not utilizing its productivity to the fullest, and inefficiency prevails. If quota market exists then household B will purchase quotas from household A[6] and achieve an efficient outcome as a whole; i.e., equation (7) is satisfied for both households. Lastly, with optimal harvest level determined, the budget constraint is set. The level of consumption is then determined by the first order conditions with respect to each consumption good.

Note that here we solved the profit maximization and utility maximization problems simultaneously, but it is easy to verify that the same result can be obtained by maximizing profit first and then maximizing the utility. This implies that the problem is recursive; i.e. the decision on consumption of goods does not influence the production decision. In this case, results from treating a fisherman as a household or as a mere producer yield no difference.

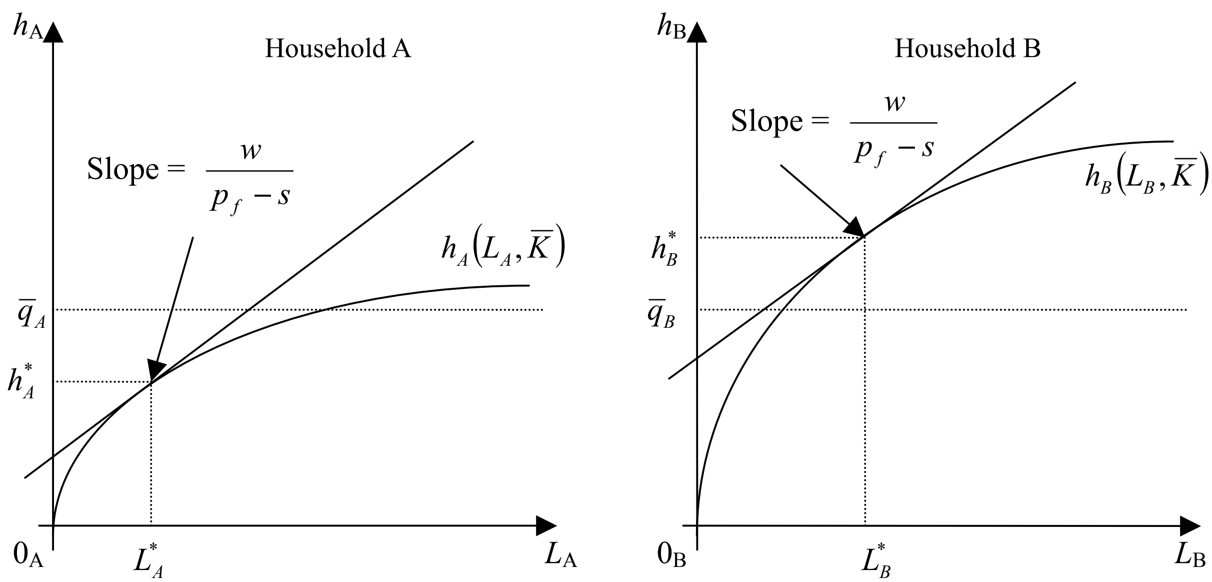

Figure 1. Quotas redistribution and optimal harvest level under perfect markets

Labor market imperfection

In this section I impose a market constraint that a fishing household can neither hire outside labor nor send its family labor to non-fishing jobs. A household could face such a constraint if labor market do not exist, or it exists but a household decided not to participate due to factors such as high transaction cost. The definition of market imperfection is not commodity specific but household specific (de Janvry, Fafchamps and Sadoulet), and therefore the labor market constraint can exist much more common than one might expect.

The maximization problem of a household i can be written as:

$$\max_{x_f^i, x_m^i, x_l^i, L_i, q_i} \quad u_i\left(x_f^i, x_m^i, x_l^i\right)$$

$$\text{subject to:} \quad p_f x_f^i + p_m x_m^i \le \pi_i$$

$$\pi_i = p_f h_i\left(L_i, \overline{K}_i\right) - s\left[q_i - \overline{q}_i\right]$$

$$h_i\left(\cdot\right) \le q_i\,, \quad F_i \equiv \overline{T}_i - x_l^i \equiv L_i$$

Note that labor cost term in the profit equation has dropped out, and all labor input L_i is supplied by family labor, F_i. Lagrangian is defined as:

(8) $$\Omega_L = u_i\left(x_f^i, x_m^i, x_l^i\right) - \lambda_i\left\{p_f x_f^i + p_m x_m^i - p_f h_i\left(L_i, \overline{K}_i\right) + s\left(q_i - \overline{q}_i\right)\right\} - \mu_i\left\{h_i\left(L_i, \overline{K}_i\right) - q_i\right\}$$
$$+ \gamma_i\left(\overline{T}_i - x_l^i - L_i\right)$$

Kuhn-Tucker first order necessary conditions are:

(9) $$x_f^i: \quad \frac{\partial u_i}{\partial x_f^i} - \lambda_i p_f = 0$$

(10) $$x_l^i: \quad \frac{\partial u_i}{\partial x_l^i} - \gamma_i = 0$$

(11) $$L_i: \quad \frac{\partial h_i}{\partial L_i}\left(p_f - \frac{\mu_i}{\lambda_i}\right) = \frac{\gamma_i}{\lambda_i}$$

(12) $$q_i: \quad s = \frac{\mu_i}{\lambda_i}$$

(13) $$\mu_i: \quad h_i\left(L_i, \overline{K}_i\right) - q_i \le 0, \qquad \mu_i\left\{h_i\left(L_i, \overline{K}_i\right) - q_i\right\} = 0$$

Assume total amount of quotas is binding, so that from proposition we have $h_i^* = q_i$ for all household. From equations (11) and (12) we obtain:

(14) $$\frac{\partial h_i}{\partial L_i} = \frac{\omega_i}{p_f - s}$$

where $\omega_i \equiv \frac{\gamma_i}{\lambda_i}$ at optimum.

ω_i can be interpreted as household-specific shadow wage or marginal shadow value of time. The level of ω_i can differ among households depending on their marginal utility of time (γ_i), which in turn is affected partially by the endowment of time ($\overline{T}_i$). Notice that this household utility maximization problem is no longer recursive as we saw in the previous section. Optimal harvest level, and hence the optimal labor input level, is partially determined by the level of ω_i. But ω_i is endogenous that is affected by the household's decision on leisure consumption. There is a feedback flow from consumption decision to production decision.

This leads to a possibility that, for some level of ω_i, less productive household purchases quota from more productive household. This is illustrated in figure 2 with the same two-agent model presented in previous section. From equation (14), the optimal harvest level occurs at the point where the slope of harvest function is equal to $\frac{\omega_i}{p_f - s}$. Since household A has more time endowment ($\overline{T}_A > \overline{T}_B$) by assumption, shadow wage will be lower than that of household B, i.e. $\omega_A < \omega_B$ and thus $\frac{\omega_A}{p_f - s} < \frac{\omega_B}{p_f - s}$, *ceteris paribus*. As shown in figure 2, less productive household A purchases additional quota ($h_A^* - \overline{q}_A$) while more productive household B sells quota ($\overline{q}_B - h_B^*$).

The result depicted in figure 2 is not the only possible outcome for the case of missing labor market. Which outcome prevails depend on the relative degree of household-specific shadow wage, which itself is affected by various attributes. Whether such outcome as in figure 2 prevails is an empirical issue. It is important, nevertheless, to acknowledge the downside risk of implementing the individual transferable quotas system in the presence of missing labor market. Some discussions on this matter are presented in the conclusion.

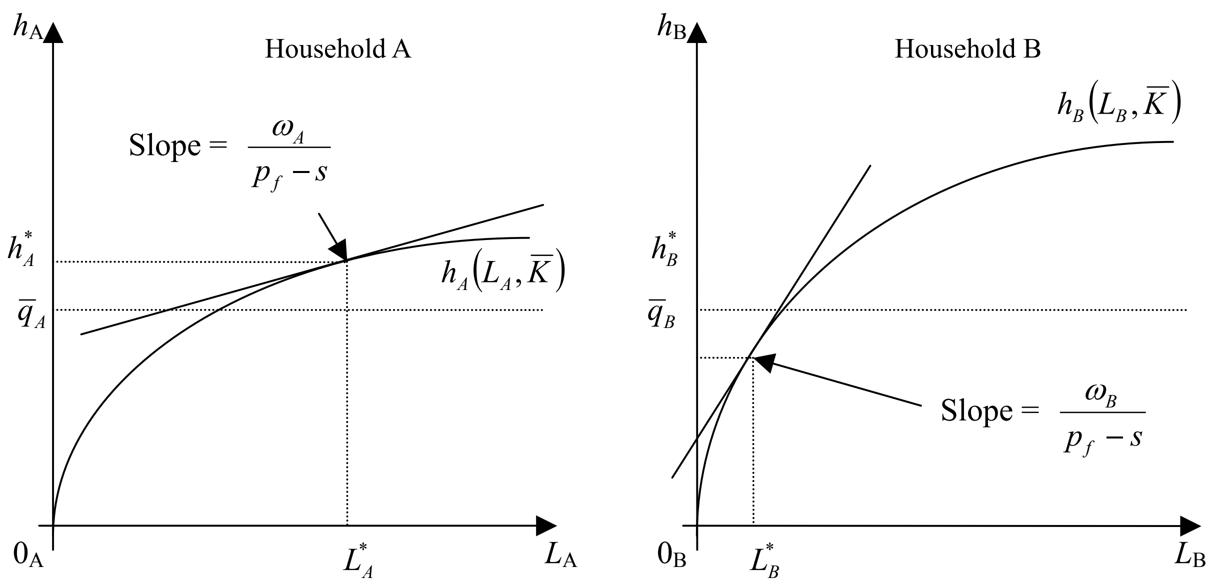

Figure 2. Quotas redistribution and optimal harvest level missing labor market

Conclusion

Using a simple household model, I have shown that under the labor market imperfection the individual transferable quotas system could transfer the quotas from more productive household to less productive household. This is the opposite of what many literatures on individual transferable quotas indicate. This article showed that same efficient result can be obtained with the household model under the assumption that all markets are perfect. Thus, whether the individual transferable quotas system would function as expected depends on the market environment surrounding that particular targeted region.

What are the effects of quotas being adversely redistributed? We know that the trade is beneficial for both fishing households; no household will engage in the trade if they know that their welfare will diminish after the trade. Thus, if any negative effects exist due to quotas trade under the missing labor market, it must be in the form of externalities outside the concerns of households.

One possible negative effect is the waste of resources. In the model, I assumed only one variable input, namely labor, but in reality there are multiple inputs for harvesting. As less productive fishing household expands (or maintain at higher level of) harvesting, more inputs are committed than what it would have been under the perfect markets case. This could be either in physical material resource, such as trees for boats or gasoline to operate the boats, or in financial resource, or both. Assuming markets other than labor market are perfect, these extra inputs could have been diverted to other and potentially more efficient use.

As aforementioned, the model implies that the occurrence of such adverse redistribution of quotas is one of the possibilities when individual transferable quotas system is implemented under market imperfection. Whether or not it actually occurs is an empirical issue, which is specific to the targeted region. The implication of this article is that, because there is this possibility of adverse redistribution of quotas, one can no longer claims that the individual transferable quotas system is the first-best solution to fishery management in any regions and/or cases. When the existence of market imperfection is suspected a careful assessment of the consequence of implementing the individual transferable quotas is critical, and in some cases alternative management regimes may need to be considered.

Footnotes

[1] In the context of fisherman household in a developing country, it is plausible to assume that capital inputs, such as boats and gears, are fixed in the short-run.

[2] Notice that $\bar{q}_i \geq \tilde{h}_i$ for $\forall i$ is sufficient, but not necessary for $s = 0$ to occur.

[3] Recall that the quota price is fixed and faced by all households, as assumed in this model.

[4] If $p_f \leq s$ then every household will find profitable (or indifferent if equality holds) to sell off their quota rather than harvesting, and hence there would be no fishing activities.

[5] For example, household A has more working-age family member than household B.

[6] Quota supplied and demanded must equalize from the fact that total quota being set is binding and the market must clear at equilibrium.

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