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# Fishery share systems and ITQ markets: who should pay for quota?

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# Fishery share systems and ITQ markets: who should pay for quota?

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# Fishery share systems and ITQ markets: who should pay for quota?

*Abstract* Although, in most commercial fisheries, fishing crews are remunerated under a share system, the implications of share systems for ITQ markets have received relatively little attention. In this paper we explore the impact of extending crew shares of vessel operating costs to include the cost of quota. We find that efficiency is maintained as long as any share system is adopted across the entire fleet. Making crews pay a share of quota costs, however, simply inflates the quota price at their expense: at market equilibrium the vessel owner's total profit share is unaffected. We also consider the outcome if only net purchasers of quota involve crews in the cost of quota. Here, all vessel owners benefit, while all crews see a reduction in their earnings. These results are illustrated with a simple numerical example. The implications for resource rent capture policies are briefly considered.

Keywords: fisheries; ITQs; quota markets; share payments; resource rent

## 1. Introduction

In many, if not most, commercial fisheries, fishing crews are rewarded under a share or "lay" system (e.g., Sutinen, 1979; Anderson, 1982; McConnell and Price, 2006). Despite this, economic models of the fishery tend either to treat labour costs in a similar way to other variable costs, i.e., as related to harvest or fishing effort, or to assume (implicitly at least) that labour is paid a fixed wage. If instead there is a share system of crew remuneration, and if the owners of fishing vessels make decisions based solely upon *their* shares of the costs and benefits to the firm, this may have significant implications for economic outcomes in the fishery.

A case in point is the use of ITQs (individual transferable quotas) in fisheries management. ITQ systems are now widely employed in commercial fisheries in order to achieve efficient regulation of harvest rates. Whereas, in almost all such fisheries, crews are remunerated using a share system, it is common for quota costs to be borne entirely by the vessel owner, as in Iceland and Australia, for example. Elsewhere, the fact that the costs of quota leasing appear as additional financial costs to individual firms has led to a practice of sharing quota costs between owner and crew, along with other variable operating costs. This is now the norm in the UK, for example, where revenues and operating costs (including the costs of quota leasing) are generally split 50:50 between owner and crew.[1] It is not immediately clear, however, what consequences this will have for the economic performance of the fleet and for the earnings of vessel owners and their crews.

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[1] Although the UK does not have a formal ITQ system as such, the arrangements for devolved quota management allow a significant amount of quota trading to take place in practice, particularly in the in-year (lease) market.

The central aim of this paper is to examine the implications of sharing the cost of quota for the generation and distribution of economic profits in an ITQ fishery. Although there is a large theoretical literature on ITQs, few authors have considered the implications of share payments for the properties of ITQ markets. Anderson (1999) examines the long run efficiency of the fleet under an ITQ system when the crew are paid on a share basis, concluding that full long run efficiency can only be achieved if the vessel owner and the crew have equal shares of both quota costs and what we will refer to as "operating profits" (revenues minus non-labour variable costs). If owners pay all the quota costs, long run efficiency cannot be achieved, it is held, since individual vessels harvest too little and the fleet will be too large as a consequence. Hannesson (2000) finds that the vessel owner's decision to invest in ITQs under a share system is distorted if a share of profits is paid to the crew, and argues that over-investment in physical capital may occur as a result. McConnell and Price (2006) consider the allocative efficiency of ITQs with a share system and show that the quota market will be inefficient if the owner's shares of revenues and non-labour harvesting costs are different. In these analyses, only Anderson (1999) explicitly considers the relationship between the share rate and the price at which quota is traded between vessels, but he does so in the context of a long run industrial equilibrium, with adjustments in both fleet and stock size, and with the same shares pertaining for both quota costs and operating profits throughout.

Our focus in the present paper is rather different. We are interested here in the *relative* share rates for quota costs and operating profits, rather than the share rate *per se*, and the impact these have on economic profits and the quota price, as well as the earnings by owner and crew. We find that the equilibrium quota price is sensitive to the difference between the owner's share of operating profits and his share of quota costs. While this may not be unexpected, what is perhaps less intuitive is that changes in the owner's share of the cost of quota *have no effect* upon his total profit share when shares are the same across the entire fleet. All the impacts of resultant changes in the quota price are felt by the crew, who experience a loss or gain in income as a result. We also examine a situation in which net sellers of quota are reluctant to share quota income with the crew, while net purchasers of quota share their quota costs. Here we find that both categories of vessel owner are better off under a sharing arrangement, whereas both crews see a loss in income.

The paper proceeds as follows. Section 2 sets up a basic model of a fishing firm in an ITQ market with crew shares. The implications of crew shares of quota costs are then explored in the following two sections, firstly assuming that shares are the same for all vessels in the fleet and then assuming that only net purchasers of quota share quota costs. Section 5 provides a numerical illustration of the results, while a final section concludes.

## 2. A fishing firm model with ITQs and crew shares

For a representative fishing vessel firm in an ITQ fishery, total short run profits as a function of harvest $q_i$ and quota demand $Q_i$ are given by

$$B_i\left(q_i\right) - r\left[Q_i - \bar{Q}_i\right], \tag{1}$$

where $r$ is the quota rental (lease) price and $\bar{Q}_i \geq 0$ is the firm's initial quota endowment (or, equivalently, the quantity of quota held by the firm as a capital asset). The social benefit (or "operating profits") function $B_i(q_i)$ is simply defined as

$$B_i(q_i) \equiv pq_i - c_i(q_i), \tag{2}$$

where $p$ is the market price for output and $c_i(q_i)$ are (non-labour) variable harvesting costs. As is usual, we assume convex costs, so that $c_i''(q_i) > 0$ and hence $B_i''(q_i) < 0$.

Let the vessel owner's shares of operating profits and quota lease costs be given by $0 < \alpha_i < 1$ and $0 < \gamma_i \leq 1$ respectively. The crew's shares of operating profits and quota costs are therefore $0 < [1 - \alpha_i] < 1$ and $0 \leq [1 - \gamma_i] < 1$. Assuming quota compliance, the owner's profit maximisation problem is then

$$\max_{q,Q} \quad \pi_i^o \equiv \alpha_i B_i(q_i) - \gamma_i r\left[Q_i - \bar{Q}_i\right] \quad \text{s.t.} \quad q_i \geq 0,\ Q_i \geq 0,\ Q_i \geq q_i. \tag{3}$$

From the first order (Kuhn-Tucker) conditions for a solution to (3), it is straightforward to find the owner's optimal decision rule for $q_i^* = Q_i^* > 0$ as

$$B_i'(q_i^*) = \frac{\gamma_i}{\alpha_i} r, \tag{4}$$

where $B_i'(q_i^*) \equiv p - c_i'(q_i^*)$. Note that, if $\gamma_i = \alpha_i$, this expression is identical to the decision rule for the owner of a firm whose labour costs are parametric.

Clearly, for marginal social benefits (and hence marginal social costs) to be equated across all firms in the fishery, we require either $\gamma_i = \alpha_i$ for all firms, or, if $\gamma_i \neq \alpha_i$, the shares $\alpha_i$ and $\gamma_i$ to be the same for each firm. Otherwise, the quota allocation will not be efficient (except by chance). Notice that, where $\gamma_i \neq \alpha_i$, efficiency does not depend upon the values of shares $\alpha_i$ and $\gamma_i$ *per se*, only on whether they have the same values for every vessel in the fleet. We return to this in the next section.

In order to examine the quota market implications of different share arrangements, we go on to consider two scenarios: firstly, one in which any change in the owner's quota share relative to his share of operating profits occurs across all vessels simultaneously; secondly, one in which a change in the owner's quota share affects only some vessels in the fleet.

## 3. Crew shares are the same for all firms

To begin with, we assume that at market equilibrium the shares $\alpha_i$ and $\gamma_i$ are the same across all vessels in the fleet. We can therefore treat a single vessel as a model for the entire fleet.[2]

Suppose we have $\gamma > \alpha$ and hence, from equation (4), $B'(q^*) > r$. This implies that the equilibrium quota price is less than the marginal benefit of harvest to the firm. Not surprisingly, if the owner bears a disproportionately large share of the cost of quota, quota is traded at below its marginal value to the firm as a whole. If $\gamma < \alpha$, on the other hand, then $B'(q^*) < r$ and quota is overvalued with respect to its marginal benefit to the firm.

Totally differentiating (4) and rearranging, we can obtain an expression for the slope of the owner's quota demand curve as

$$\frac{dQ(r)}{dr} = \frac{dq(r)}{dr} = \frac{\gamma}{\alpha} B''^{-1}(\centerdot) < 0, \tag{5}$$

where $B''^{-1}(\centerdot)$ is the slope of the inverse of $B'(q)$.[3] All else equal, the greater is the owner's share $\gamma$ in the cost of quota, the more (price) elastic is his demand for quota and

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[2] Individual subscripts are accordingly dropped for this section.

[3] We assume that, for all $q \geq 0$, the function $B'(q)$ has an inverse $B'^{-1}(\centerdot)$. By the inverse function rule, we then have $B''^{-1}(\centerdot) \equiv 1/B''(q)$.

hence the lower is his quota demand at any given quota price. As a result, the industry *inverse* quota demand will become less elastic as $\gamma$ increases and more elastic as $\gamma$ is reduced, relative to $\alpha$. For a given total quota supply (TAC), therefore, the equilibrium quota price is reduced if $\gamma > \alpha$ and increased if $\gamma < \alpha$. Changes in *both* $\gamma$ and $\alpha$ which leave the ratio $\gamma/\alpha$ unaltered, on the other hand, will have no effect upon quota demands and hence the equilibrium quota price.

Notice that $\gamma \neq \alpha$ in expression (4) implies that total firm profits are not maximised by the vessel owner. From (1) we would expect total profits for both owner and crew to be maximised where $B'(q^*) = r$. If, instead, the firm operates where $B'(q^*) > r$ for example, it appears to underproduce for the observed quota price. But in this case, as we have seen, the equilibrium quota price will be lower than it would be if all firms set $B'(q^*) = r$. All else equal, if the quota market clears then output for the representative firm must be unchanged by a change in $\gamma$ and hence a change in the quota price $r$. Therefore, total *economic* profits will be unaffected by an increase or a decrease in $\gamma$: there is simply a concomitant reduction or increase in the value of quota.

In order to examine this further, let $\tilde{r}$ be the equilibrium quota price when $\tilde{\gamma} = 1 > \alpha$. Then from (4) we have

$$B'(q^*)\big|_{\gamma>\alpha} = \frac{\tilde{\gamma}}{\alpha}\tilde{r} = \frac{1}{\alpha}\tilde{r}. \tag{6}$$

If we reduce $\gamma$ from $\gamma = 1$ to $\gamma = \alpha$, holding $\alpha$ constant, then we will have

$$B'(q^*)\big|_{\gamma=\alpha} = \frac{\gamma}{\alpha}r = r. \tag{7}$$

If there is no change in the output of the representative firm, then

$$B'(q^*)|_{\gamma>\alpha} = B'(q^*)|_{\gamma=\alpha} \tag{8}$$

and therefore

$$r = \frac{1}{\alpha}\tilde{r}, \tag{9}$$

which implies that $r > \tilde{r}$. Assume that the firm is a net purchaser of quota, i.e., $Q^* > \bar{Q}$. When $\tilde{\gamma} = 1$, the cost to the owner of a unit of quota is $\tilde{\gamma}\tilde{r} = \tilde{r}$. If $\gamma$ is reduced to $\gamma = \alpha$, the owner's unit quota costs are now $\gamma r$. But, if $\alpha$ is unchanged, we can observe that

$$\gamma r = \gamma\frac{1}{\alpha}\tilde{r} = \tilde{r}. \tag{10}$$

Hence, if $q^* = Q^*$ has not changed, the owner's quota costs have not changed! Since there has also been no change in the owner's share of operating profits $\alpha B(q^*)$, we can see that making the crew pay a share of the quota costs merely inflates the quota price at their expense: *at market equilibrium there is no net gain to the vessel owner.*

We get the opposite result if $\gamma$ is increased from $\gamma = \alpha < 1$ to $\gamma = 1$, again holding $\alpha$ constant. Now, if the firm is a net purchaser of quota, we will see a reduction in the equilibrium quota price and an increase in crew remuneration: a transfer from the total cost of quota to the total earnings of the crew.

It is relatively straightforward to show that if the firm is a net seller of quota (and we assume that the income from quota leasing is shared *pro rata* with the crew - see below) then the impacts on crew remuneration from a change in $\gamma$ are simply reversed. Thus, all else equal, an increase in $\gamma$ implies a reduction in both total quota income and total crew remuneration, while a reduction in $\gamma$ implies an increase in total quota income and crew remuneration. At market equilibrium, therefore, sharing the income from quota leasing with the crew has no negative impact on the owner's profits.

In each case, although the total value of quota changes with changes in $\gamma$ relative to $\alpha$, the total economic profits in the fishery remain unchanged since, with $\gamma$ and $\alpha$ the same across the fleet, the allocation of quota continues to be efficient.

## 4. Crew quota shares differ across vessels

Although sharing the cost of quota with the crew has no impact upon the owner's total share of the profits (operating profits less quota costs, or plus quota income) when all vessel firms behave similarly, there is clearly a temptation for vessel owners who are net *sellers* of quota to retain a 100% share of quota income. We therefore examine the quota market outcome if only net buyers of quota reduce the owner's quota share $\gamma_i$.

Consider a fishery consisting of just two representative (price-taking) vessels. Although we will assume that the vessels are otherwise identical, the quota endowments $\bar{Q}_i$ are such, we assume, that Vessel 1 leases quota to Vessel 2. Let the initial quota shares be $\gamma_i = 1 > \alpha_i, i = 1, 2$, the same for both vessels. To begin with, therefore, both vessels operate where

$$B_i'(q_i^*) = \frac{1}{\alpha_i} r, \quad i = 1, 2. \tag{11}$$

Now consider what happens if Vessel 2, a net purchaser of quota, reduces $\gamma_2$ to $\gamma_2 = \alpha_2 < 1$. The industry equilibrium quota price must increase, since Vessel 2's quota demand will become less elastic as a result. Because Vessel 1's decision rule stays the same as (11), its output is reduced in response to the increased quota price and hence it leases more quota to Vessel 2, which therefore expands its output. Note that Vessel 2 now operates where

$$B_2'(q_2^*) = \frac{\gamma_2}{\alpha_2} r = r, \tag{12}$$

and therefore $B_2'(q_2^*) < B_1'(q_1^*)$, which, if the vessels are identical, confirms that now $q_2^* > q_1^*$. The result is nevertheless robust to asymmetry in the fleet, as the numerical example in Section 5 will demonstrate.

In the new market equilibrium, Vessel 1's owner benefits from increased quota leasing at an increased quota price, although his share of operating profits is reduced as the vessel's output is reduced. Employing the Envelope Theorem, however, we can see from the Lagrangian for (3) that

$$\frac{d\pi_1^o}{dr} = -\gamma_1 \left[Q_1^* - \bar{Q}_1\right] > 0, \tag{13}$$

which is unambiguously positive for a net seller of quota. Vessel 1's crew, on the other hand, clearly lose out since they only get a share of operating profits, which are reduced. Vessel 2 increases its output and hence total operating profits, and both the owner's and the crew's shares of operating profits are therefore increased. While total quota costs are increased, these are now split between the owner and the crew. From

$$\frac{d\pi_2^o}{d\gamma_2} = -r \left[Q_2^* - \bar{Q}_2\right] < 0, \tag{14}$$

however, we can see that, given $Q_2^* > \bar{Q}_2$, the owner of Vessel 2 will always derive a net benefit from a reduction in $\gamma_2$. Since the total crew remuneration (profit share) for Vessel 2 is given by

$$\pi_2^c \equiv [1 - \alpha_2] B_2(q_2^*) - [1 - \gamma_2] r \left[Q_2^* - \bar{Q}_2\right], \tag{15}$$

we can find

$$\frac{d\pi_2^c}{d\gamma_2} = [[1-\alpha_2]\, B_2'(q_2^*) + \gamma_2 r]\, \frac{dq_2^*}{d\gamma_2} + r\left[Q_2^* - \bar{Q}_2\right], \tag{16}$$

which uses $Q_2^* = q_2^*$. Given that the vessel owner ensures that $\alpha_2 B_2'(q_2^*) = \gamma_2 r$, this reduces to

$$\frac{d\pi_2^c}{d\gamma_2} = B_2'(q_2^*)\, \frac{dq_2^*}{d\gamma_2} + r\left[Q_2^* - \bar{Q}_2\right] \gtreqless 0. \tag{17}$$

As the first term on the RHS is negative and the second term is positive, the sign of this expression appears ambiguous. However, since the change in crew income from a marginal change in $\gamma_2$ is related to the *marginal* change in operating profits but the *total* cost of quota, we can conclude that the second term dominates and hence that the sign of (17) is positive. Thus, a reduction in $\gamma_2$ leads to a net reduction in crew remuneration for Vessel 2.

Finally, notice that while the total value of quota increases, the total economic profit in the fishery will decrease, since the allocation of quota is now inefficient.

## 5. A numerical example

We illustrate the above using a simple numerical example with just two vessels in the fleet. To give a specific functional form to (3), let

$$\pi_i^o \equiv \alpha_i \left[p q_i - \frac{1}{2} c_i q_i^2\right] - \gamma_i r\left[Q_i - \bar{Q}_i\right], \quad i = 1, 2. \tag{18}$$

The first order conditions for the vessel owners' optimal choices of $q_i^* = Q_i^*$ are then

$$\alpha_i\left[p - c_i q_i^*\right] = \gamma_i r, \quad i = 1, 2. \tag{19}$$

Solving for $r$, and substituting using $\boldsymbol{Q} \equiv Q_1^* + Q_2^* = \bar{Q}_1 + \bar{Q}_2$, we can employ a little manipulation to find

$$Q_1^* = q_1^* = \frac{p\left[\dfrac{\alpha_1}{\gamma_1} - \dfrac{\alpha_2}{\gamma_2}\right] + \dfrac{\alpha_2}{\gamma_2} c_2 \boldsymbol{Q}}{\dfrac{\alpha_1}{\gamma_1} c_1 + \dfrac{\alpha_2}{\gamma_2} c_2}, \tag{20}$$

together with a similar expression for $Q_2^*$, as well as

$$r = \frac{p\dfrac{\alpha_1}{\gamma_1}\left[c_1 + c_2\right] - \dfrac{\alpha_1}{\gamma_1} c_1 c_2 \boldsymbol{Q}}{\dfrac{\alpha_1}{\gamma_1} \cdot \dfrac{\gamma_2}{\alpha_2} c_1 + c_2}. \tag{21}$$

Given the parameters $p$ and $\bar{Q}_i$ as well as the cost coefficients $c_i$, we can then calculate the equilibrium quota market outcomes for any combination of the shares $\alpha_i$ and $\gamma_i$.

Let $p = 10$, $\bar{Q}_1 = 100$ and $\bar{Q}_2 = 20$, with $c_1 = 0.1$ and $c_2 = 0.05$. Notice that we have now relaxed the assumption that the vessels are identical, since here Vessel 2 is clearly more efficient than Vessel 1, although its initial quota endowment is smaller.

Table I shows the quota market outcome when $\alpha_1 = \alpha_2 = 0.5$ and $\gamma_1 = \gamma_2 = 1$. Vessel 1 leases 60 units of quota to Vessel 2 at an equilibrium price of 3. Total economic profits in the fishery are 960, of which 360 is captured in the value of quota. In Table II, we show the results when both $\gamma_i$ shares are reduced to equal the $\alpha_i$ shares. Notice that the (efficient) quota allocation is unchanged, as are the total economic profits in the fishery. Now, however, the value of quota is doubled and the impact of this is entirely felt by the crew. The crew of Vessel 1 more than double their income (from 160 to 340) while the crew of Vessel 2 see their total remuneration reduced from 320 to 140.

Table III shows the outcome when only Vessel 2 reduces $\gamma_2$ to equal $\alpha_2$, while Vessel 1 retains $\gamma_1 = 1$. Compared to the outcome in Table I, we can see that although the total value of quota is increased, total profits in the fishery are reduced since the quota allocation is now inefficient. The owner of Vessel 1 gains as a result of the increased leasing of quota to Vessel 2, but Vessel 1's crew lose out. As predicted, there is also a net gain for the owner of Vessel 2, while the crew of Vessel 2 suffer a net loss in income.

## 6. Conclusion

We have shown that, all else equal, changes in the share of quota costs paid by the vessel owner, when applied across the whole fleet, have an impact upon the equilibrium quota price but do not change the owner's total profit share. The effects of changes in the quota price fall entirely upon the crew, who gain or lose a share of profits as a result. We have also seen that the efficiency of quota allocation is maintained as long as the owners' shares of quota costs and operating profits are consistent across the fleet: there is no requirement for these shares to be equal.

Given this, if the fixed (capital) costs of the vessel are covered by the owner's share of the total profits, as is usually the case, there appear to be no implications for long run efficiency if there are changes across the fleet in the owners' share of quota costs. A positive crew reservation wage on the other hand, which represents a quasi-fixed cost to be covered by the crew share of operating profits, may impose an upper limit on the percentage of quota costs which can be borne by the crew.

If only some vessel owners share quota costs with the crew (and we assumed that net sellers of quota might be reluctant to do so) we saw that quota allocation would no longer be efficient and that total economic profits in the fishery would be reduced as a result.

Nevertheless, the equilibrium quota price would still increase, and all vessel owners would benefit at the expense of their crews.

Although there seems to be a widespread reluctance on behalf of the governments of fishing nations to attempt to extract resource rents from the industry, a share system which effectively increases the proportion of economic profits which are reflected in the value of quota has interesting implications for rent capture policies (see, for example, Grafton, 1992; 1995). At the very least, the generation of resource rents in the fishery is more accurately measured than in a share fishery where crew do not share in the cost of quota, since a part of the resource rent paid to the crew is now transferred to the value of quota. In consequence, a tax on quota value has the potential to capture a greater proportion of resource rents.

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|  | **Vessel 1** |  |  | **Vessel 2** |  |  |
|---|---|---|---|---|---|---|
|  | $\alpha_1 = 0.5$ | $\gamma_1 = 1.0$ | $Q_1^* = 40$ | $\alpha_2 = 0.5$ | $\gamma_2 = 1.0$ | $Q_2^* = 80$ |
|  | Total | Owner | Crew | Total | Owner | Crew |
| $B\left(q_i^*\right)$ | 320 | 160 | 160 | 640 | 320 | 320 |
| $-r\left[Q_i^* - \bar{Q}_i\right]$ | 180 | 180 | 0 | $-180$ | $-180$ | 0 |
| $B\left(q_i^*\right) - r\left[Q_i^* - \bar{Q}_i\right]$ | 500 | 340 | 160 | 460 | 140 | 320 |
| $\sum_{i=1}^{2} B\left(q_i^*\right) = 960$ | $r = 3$ |  |  |  |  |  |

Table I.

| | **Vessel 1** | | | **Vessel 2** | | |
|---|---|---|---|---|---|---|
| | $\alpha_1 = 0.5$ | $\gamma_1 = 0.5$ | $Q_1^* = 40$ | $\alpha_2 = 0.5$ | $\gamma_2 = 0.5$ | $Q_2^* = 80$ |
| | Total | Owner | Crew | Total | Owner | Crew |
| $B\left(q_i^*\right)$ | 320 | 160 | 160 | 640 | 320 | 320 |
| $-r\left[Q_i^* - \bar{Q}_i\right]$ | 360 | 180 | 180 | $-360$ | $-180$ | $-180$ |
| $B\left(q_i^*\right) - r\left[Q_i^* - \bar{Q}_i\right]$ | 680 | 340 | 340 | 280 | 140 | 140 |
| $\sum_{i=1}^{2} B\left(q_i^*\right) = 960$ | $r = 6$ | | | | | |

Table II.

|  | **Vessel 1** |  |  | **Vessel 2** |  |  |
|---|---|---|---|---|---|---|
|  | $\alpha_1 = 0.5$ | $\gamma_1 = 1.0$ | $Q_1^* = 10$ | $\alpha_2 = 0.5$ | $\gamma_2 = 0.5$ | $Q_2^* = 110$ |
|  | Total | Owner | Crew | Total | Owner | Crew |
| $B\left(q_i^*\right)$ | 95 | 47.5 | 47.5 | 797.5 | 398.75 | 398.75 |
| $-r\left[Q_i^* - \bar{Q}_i\right]$ | 405 | 405 | 0 | $-405$ | $-202.5$ | $-202.5$ |
| $B\left(q_i^*\right) - r\left[Q_i^* - \bar{Q}_i\right]$ | 500 | 452.5 | 47.5 | 392.5 | 196.25 | 196.25 |
| $\sum_{i=1}^{2} B\left(q_i^*\right) = 892.5$ | $r = 4.5$ |  |  |  |  |  |

Table III.