MONOPOLIZING INDIVIDUAL TRANSFERABLE QUOTA:

THEORY AND EVIDENCE

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Anderson's (1991) conclusion that fishing firms will never find it profitable to buy Individual Transferable Quota (ITQs) to retire and so raise fish prices depends critically upon restrictive assumptions. In particular, alternative contractual arrangements allow firms to profit by buying and retiring quota. Including stock effects provides the same result. The fear of monopolization following the introduction of ITQs cannot be dismissed theoretically. Whether or not it proves profitable to buy and retire quota to raise fish prices remains an empirical question. In New Zealand ownership of ITQs has not concentrated over time. However, substantial amounts of quota remain uncaught and the amount uncaught correlates strongly and positively with quota concentration. Most of the New Zealand catch is sold in the world market making it unlikely that quota is retired to raise fish prices. It may be that fishing firms are retiring quota to improve fish stocks and so lower fishing costs. The data are consistent with this hypothesis.

INTRODUCTION

The use of Individual Tradable Quotas (ITQs) to constrain fish harvests often raises fears of monopolization. Anderson (1991) in a recent paper argues that these fears are ill-founded. His analysis concludes that no firm would ever find it profitable to raise fish prices by buying and retiring quota. The present paper shows that Anderson's conclusion follows directly from his assumptions and that fears of monopolization cannot be so readily dismissed. The paper also reports upon the experience in New Zealand where quota oftentimes fetches a good price even though substantial amounts of quota remain uncaught.

The paper is arranged as follows. Section II reviews Anderson's model. Sections III identifies the model's critical assumptions and examines the consequences of relaxing these assumptions. Section IV reports upon the experience with ITQs in New Zealand and shows that there has been no overall trend in quota concentration over time but that the amount of quota left uncaught strongly and positively correlates with quota concentration. The bulk of the New Zealand catch is exported which likely rules out the possibility that New Zealand firms are retiring quota to raise fish prices. However, the relationship between quota concentration and quota left is consistent with the hypothesis that firms are retiring quota to improve fish stocks and so lower fishing costs — a possibility that Anderson ignores.

ANDERSON'S MODEL

Anderson's (1991) purpose is to analyze the potential effects of market power on both the market for ITQs and the market for fish. His model comprises a competitive fringe and a dominant firm. The dominant firm has the ability to raise the price of fish by not fishing quota and its decision to buy or sell quota affects quota price. A total of $\bar{Q}$ quota is allocated, and the dominant firm uses Q_1 quota and retires Q_2. The amount of quota available to the competitive fringe is thus $\bar{Q} - Q_1 - Q_2 = Q_3$. The inverse demand function for the final product is

(1) $$P = P(Q).$$

If $\bar{Q}$ is fixed, the price function becomes

(2) $$\overline{P} = \overline{P}(Q_2).$$

The equilibrium condition for the competitive fringe is

(3) $$\overline{P}(Q_2) - MC_3(Q_3) = R,$$

where $MC_3(Q_3)$ is the sum of the upward sloping marginal cost curves and R is the annual rental price of quota which fringe firms take as given. The supply price of quota is thus

(4) $$R(Q_1,Q_2) = \overline{P}(Q_2) - MC_3(\overline{Q} - Q_1 - Q_2).$$

Differentiating with respect to Q_1 and Q_2 yields

(5) $$\frac{\partial R}{\partial Q_1} = -\overset{(-)}{\frac{\partial MC_3}{\partial Q_1}} > 0,$$

and

(6) $$\frac{\partial R}{\partial Q_2} = \overset{(+)}{\frac{dP}{dQ_2}} - \overset{(-)}{\frac{\partial MC_3}{\partial Q_2}} > 0.$$

Anderson concludes from equations (5) and (6) that buying quota to retire raises quota price more than buying quota to fish. Buying quota in each case moves the fringe down its marginal cost curve, but retiring quota has the additional effect of raising the price of fish.

<u>Dominant Firm Initially Owns No ITQs</u>

Anderson proceeds with his analysis by examining two extremes in initial quota allocation. In the first extreme the dominant firm begins with no quota. The firm's profit is

(7) $$\pi = \overline{P}(Q_2)Q_1 - TC_1(Q_1) - R(Q_1,Q_2)[Q_1 + Q_2],$$

where TC_1 is its total cost function for Q_1. The first-order condition for Q_1 is

(8) $$\frac{\partial \pi}{\partial Q_1} = \overline{P}(Q_2) - MC_1(Q_1) - \frac{\partial R}{\partial Q_1}[Q_1 + Q_2] - R = 0.$$

Anderson compares equations (3) and (8) and concludes that there is an efficiency loss as the dominant firm's and the fringe's marginal costs are not equated. Equation (8) shows that the dominant firm equates marginal revenue with marginal factor cost. The dominant firm is a monopsonist and buys too little quota relative to what total cost minimization requires.

The result from equation (8) is shown graphically in Figure 1. The x-axis represents the quota split between the dominant firm and the fringe. On the extreme right, all the quota is held by the fringe. Moving leftwards, the quota held by the fringe declines to the advantage of the dominant firm. R_1 and R_3 represent the dominant firm's and the fringe's marginal willingness-to-pay for quota. The willingness-to-pay for quota is the difference between the price of fish, P_0, and the marginal cost, MC_1 or MC_3. The buying of quota by the dominant firm moves the fringe move down its marginal cost curve and the price of quota rises. The dominant firm has market power and buys quota to equate its marginal willingness-to-pay for quota, R_1, with the marginal factor cost of quota, MFC. The dominant firm buys Q_1' quota. This quantity does not allow the catch to be caught at least cost as the dominant firm's and fringe's marginal costs are not equated. The total cost minimizing allocation is for the dominant firm to fish Q_1^*.

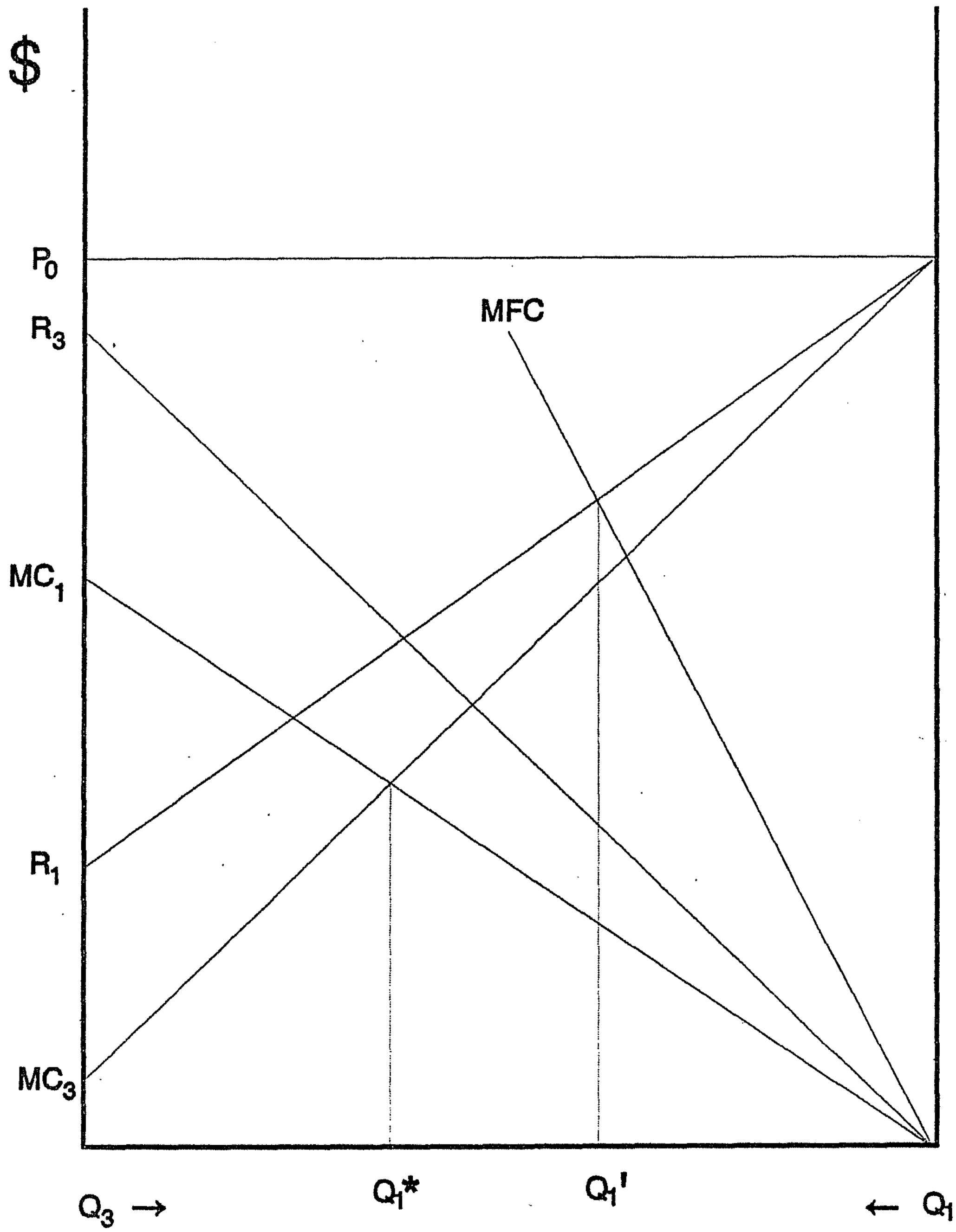

Figure 1. Buying ITQs to fish

Anderson proceeds to consider the possibility of the dominant firm buying quota to retire to raise the price of fish. The first-derivative of the profit equation with respect to Q_2 yields the first-order condition

$$(9) \qquad \frac{\partial \pi}{\partial Q_2} = \frac{d\overline{P}}{dQ_2}Q_1 - \frac{\partial R}{\partial Q_2}[Q_1 + Q_2] - R = 0.$$

Buying quota to retire proves profitable only if marginal return exceeds marginal factor cost. Using equation (6), equation (9) becomes

$$(10) \qquad \frac{d\overline{P}}{dQ_2}Q_1 - \frac{d\overline{P}}{dQ_2}Q_1 + \frac{\partial MC_3}{\partial Q_2}Q_1 - \frac{\partial R}{\partial Q_2}Q_2 - R = 0.$$

The first two terms cancel, the remaining three terms are all negative, and Anderson concludes that there is no profit in buying and retiring quota:

> The profit maximizing dominant firm which must purchase ITQs will not find it beneficial to withhold production to raise the price of the market output. The first-order profit maximizing condition for Q_2 is negative for all positive levels of Q_2. Purchasing Q_2 to restrict output and increase price will always result in decreased profits. In this case, it appears that fishery managers' fears about output price manipulation are ill founded. (p. 295).

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The firm finds it unprofitable to buy and retire quota because Anderson's model ensures that the increase in fish price is exactly matched by a gain in quota price. The dominant firm must pay this higher price on the quota it fishes and so the gain it would make on the higher fish price is entirely lost to the fringe in the higher quota price that must be paid. As well as losing all the gain in fish price in the higher price of the quota it is to fish, the dominant firm must buy the quota that it is to retire and this expenditure is a net loss. Under these conditions it can never prove profitable for a firm to buy and retire quota.

The result is shown in Figure 2. The dominant firm now buys Q_2 as well as Q_1. Retiring Q_2 increases the price of fish from P_0 to P_1. The dominant firm gains area *abcd*. However, the gain in price is matched by the increase in the fringe firms' willingness-to-pay for quota. R_3 increases to R_3' by the exact amount of the price increase. Moreover, in buying Q_2 the dominant firm moves the fringe further down its marginal cost curve to give a new quota price of R'. Clearly, the extra expenditure of buying Q_1 and Q_2 at R' rather than Q_1 at R exceeds the possible gain of area *abcd*. In this way it is never possible for the dominant firm to profit from buying quota to retire.

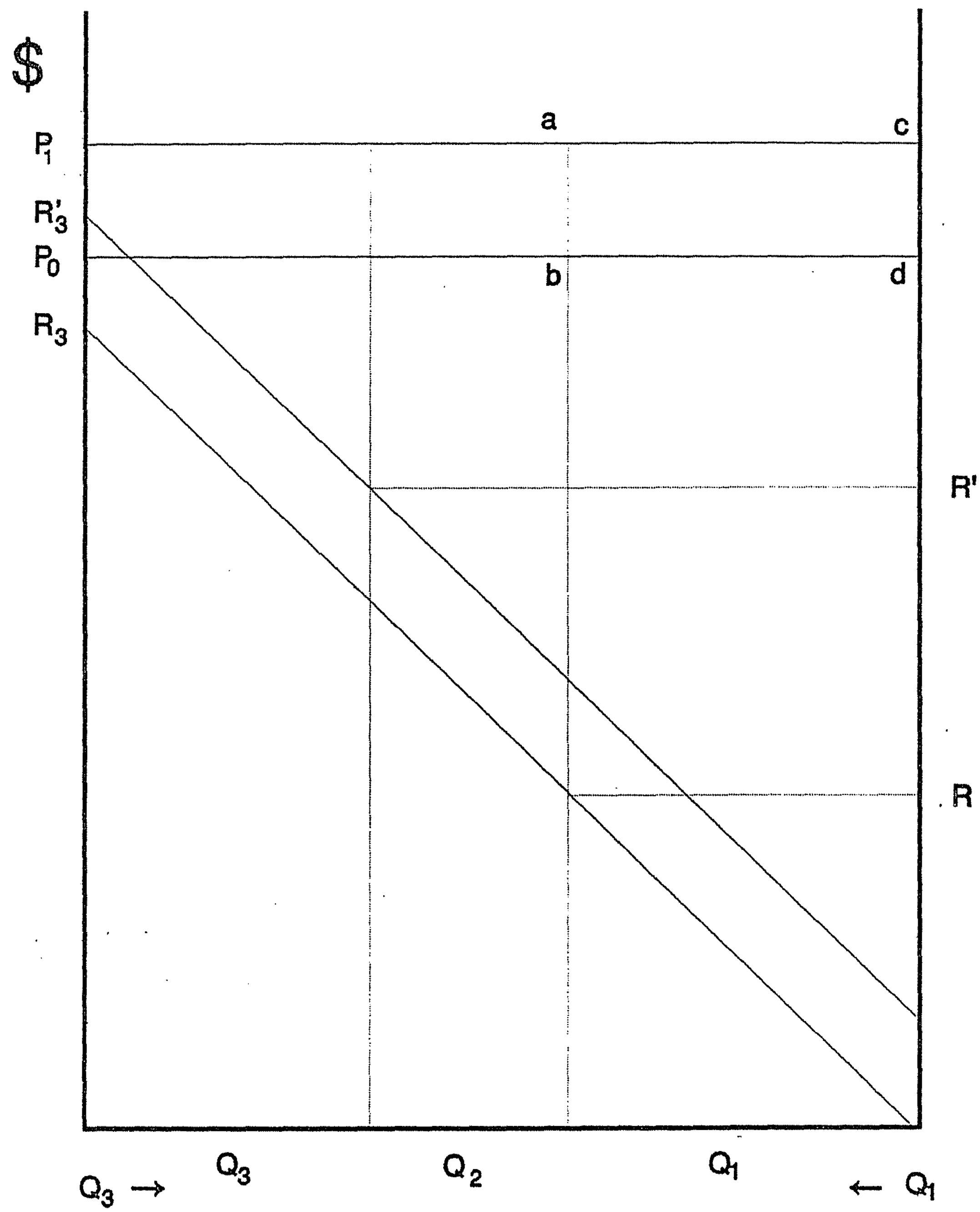

Figure 2. Buying ITQs to retire

Dominant Firm Initially Owns All ITQs

Anderson also analyzes the polar allocation where the dominant firm initially owns all the quota. The firm's profit is then

$$\pi = \overline{P}(Q_2)Q_1 - TC_1(Q_1) + R(Q_1,Q_2)[\overline{Q} - Q_1 - Q_2]. \tag{11}$$

The firm can gain revenue by using quota to produce fish or to restrict market output and also by selling the quota to the fringe. The first-order condition with respect to Q_1 is

$$\frac{\partial \pi}{\partial Q_1} = \overline{P}(Q_2) - MC_1(Q_1) + \frac{\partial R}{\partial Q_1}Q_3 - R = 0. \tag{12}$$

The dominant firm thus equates marginal cost and marginal revenue. The dominant firm is a monopolist and sells too little quota relative to what total cost minimization requires.

The first-order condition with respect to Q_2 is

$$\frac{\partial \pi}{\partial Q_2} = \frac{\partial \overline{P}}{\partial Q_2}Q_1 + \frac{\partial R}{\partial Q_2}Q_3 - R = 0. \tag{13}$$

The dominant firm retires quota to equate marginal cost (R) with marginal revenue — the increase in fish price gained at the margin multiplied by the fish caught in addition to the gain in quota price at the margin multiplied by the quota sold. A dominant firm that initially owns all the quota may find it profitable to retire quota.

Anderson concludes that the presence of a dominant firm may produce an ITQ allocation such that the total cost of harvest is not minimized but that the retiring of quota to raise fish prices is a potential problem only where the dominant firm is a net seller of quota.

EXTENDING THE MODEL

Anderson's result is curiously un-Coasian (Coase, 1960). In his model the final allocation of property rights depends upon the initial allocation. A quite different result is produced if the dominant firm initially holds no quota compared to when it initially holds all the quota. Potential gains from trade also remain unexploited. As long as the demand for fish is price inelastic over the relevant range, the dominant firm and fringe could improve their profits by agreeing to retire quota. Anderson ignores the possibility of such an agreement. Moreover, Anderson's model ignores stock effects. Retiring quota will lower fishing costs as well as raise fish prices as the stock improves owing to the reduced catch.

Dominant Firm Initially Owns Some ITQs

Anderson's conclusion also goes beyond his analysis and the resulting error needs correcting before considering stock effects and how the potential gains from trade can be realized. Anderson concludes that quota will not be retired to raise fish prices unless the dominant firm is a net seller of quota. This is incorrect. Anderson does not analyze the intermediate case where the dominant firm initially owns some quota but buys more.

This situation is most readily analyzed where the firm is buying quota only to retire. The firm's profit is now

$$\pi = \overline{P}(Q_2)Q_1 - TC_1(Q_1) - R(Q_2)Q_2. \tag{14}$$

The first-order condition for Q_2 is

$$\frac{\partial \pi}{\partial Q_2} = \frac{d\overline{P}}{dQ_2}Q_1 - \frac{\partial R}{\partial Q_2}Q_2 - R = 0. \tag{15}$$

The dominant firm once again equates marginal return to marginal factor cost. Using equation (6), equation (15) becomes

$$\frac{d\overline{P}}{dQ_2}(Q_1 - Q_2) + \frac{\partial MC_3}{\partial Q_2}Q_2 - R = 0. \tag{16}$$

A dominant firm that starts out with some quota may well find it profitable to buy additional quota to retire. The important determinants of profitability are the price elasticity of demand for fish, how much quota the firm buys relative to what it already owns, the effect buying quota has on the fringe's marginal cost, and quota price. The reason why it may now prove profitable to buy and retire quota is that the dominant firm does not now lose the gain in fish price that it achieves in the higher quota price for the quota it fishes — it already owns this quota and does not have to buy it.

The result is shown in Figure 3. The dominant firm's gain in buying and retiring quota is area *abcd* as before. However, as it only has to buy Q_2, the cost in retiring Q_2 is now only area *efhg*. As long as area *abcd* is larger than area *efhg* it will prove profitable to buy and retire quota.

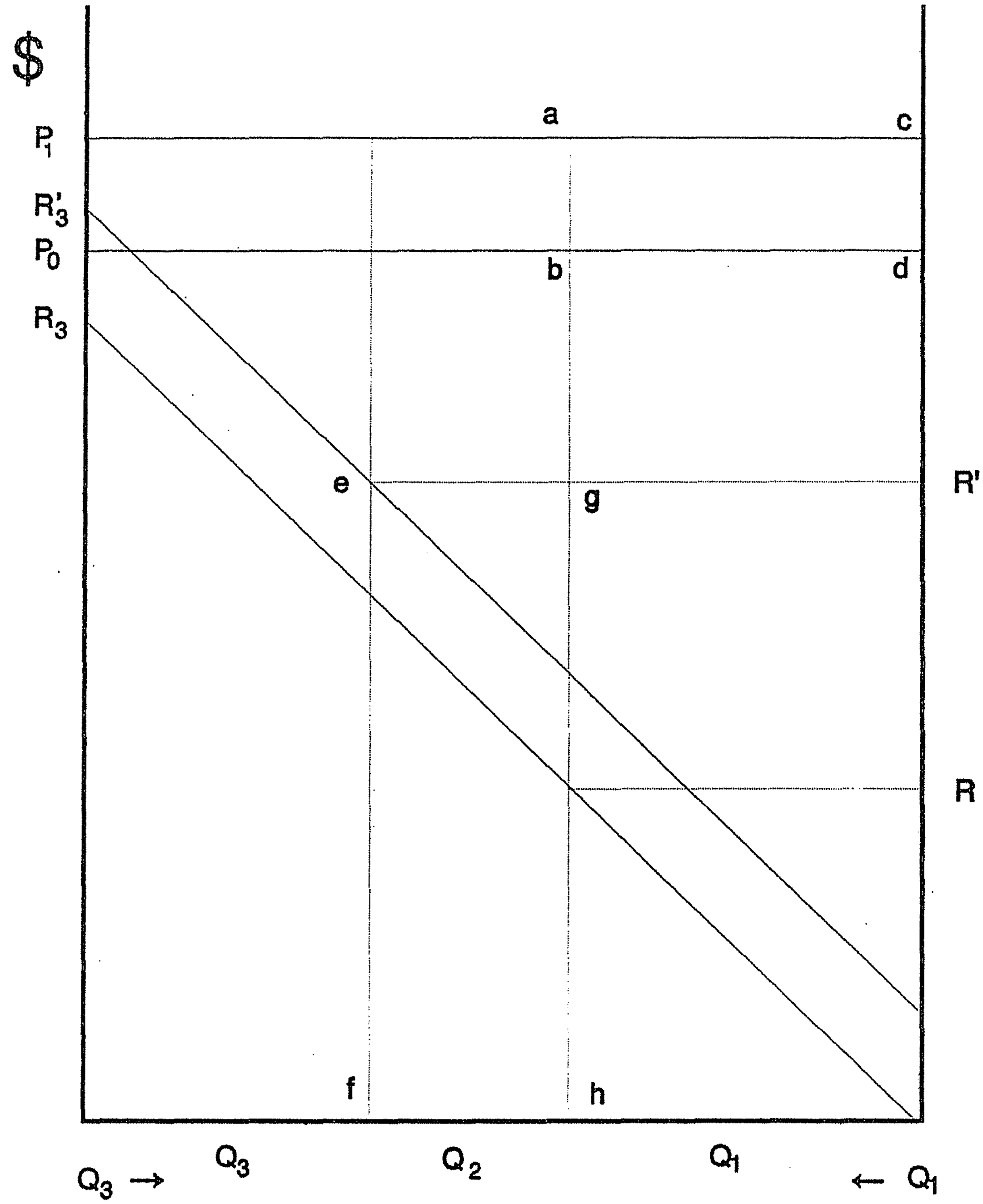

Figure 3. Buying ITQs to retire with Q_1 already owned

Anderson's conclusion that retiring quota to raise fish prices is only a potential problem where the dominant firm is a net seller of quota is thus incorrect. It may well prove profitable where the dominant firm need only buy some quota.

Alternative Contractual Arrangements

In Anderson's model, the dominant firm buys its quota at the market price. This market price equals what quota will trade for once the dominant firm has bought Q_1+Q_2 quota and retired Q_2. In such a model it never profits the firm to buy and retire Q_2. However, as long as the demand for fish is inelastic over the relevant range, it is in the fringe's and dominant firm's combined interest to retire quota and there must exist a deal that retires quota to profit both the dominant firm and the fringe.

The key to this deal is that the fringe also benefits from the retiring of quota, as its members receive the resulting higher price. As a result they will accept a price lower than the final market-clearing price for quota if they are sure that the quota is to be retired and so raise the price of fish. The trick for the dominant firm is to ensure that it can retire the quota at price that profits both parties; the problem being that there is an incentive for fringe firms to hold out so as to enjoy the higher quota price should the dominant firm's attempt to increase the price of fish prove successful.

A solution to the problem is as follows. Assume n firms make up the fringe. The dominant firm buys Q_1 quota as Anderson shows. Q_2 is the optimal amount of quota for the fishery as a whole to retire. The dominant firm offers to buy Q_2/n quota from each firm at a price R_1 with the proviso that all firms of the fringe must participate or the deal is off. The proviso makes it impossible for a fringe firm to profit from holding out; if they do not sell, no quota will be retired. If the trade is to proceed, R_1 must be such that the fringe firms profit by agreeing to sell Q_2/n. For the fringe as a whole this requires

$$(17) \qquad P_0Q_2 - [TC_3(Q_3+Q_2) - TC_3(Q_3)] - \Delta PQ_3 < R_1Q_2,$$

where P_0 is the initial price of fish and ΔP is the price change achieved by retiring Q_2 quota. P_0Q_2 is thus the revenue forgone by the fringe in selling Q_2. The term in square brackets is the total cost to the fringe of fishing Q_2 and the fringe avoids this cost by not fishing Q_2. ΔPQ_3 is the gain the fringe makes in fishing Q_3 at the higher price achieved by retiring Q_2. R_1Q_2 is the total payment made to the fringe for retiring Q_2. Equation (17) thus states that the fringe will agree to the deal as long as R_1 is such that the payment for Q_2 covers the profit it would make for fishing Q_2 net of the gain it makes selling Q_3 at the higher price.

The dominant firm will make the deal as long as R_1 is not so large as to make the total payment exceed the gain it makes through retiring Q_2. The requires that

(18) $$\Delta PQ_1 > R_1Q_2.$$

If retiring quota is to prove successful, the total gain must exceed the total cost, that is

(19) $$\Delta PQ_1 + \Delta PQ_3 > P_0Q_2 - [TC_3(Q_3+Q_2) - TC_3(Q_3)].$$

As long as this condition holds, it can be seen from equations (17) and (18) that there must be an R_1 such that all parties profit from agreeing to the trade.

The arrangement is illustrated in Figure 4. If it is to prove profitable to retire Q_2, the total gain must exceed the total cost of doing so. The total gain is area *abfe*, which is what the fringe receives through a higher on Q_3, and area *cdhg*, which is what the dominant firm receives through the higher price on Q_1. The total cost is area *fgji*, which is the profit the fringe would make if it fished Q_2. All that is required for the trade described above is for R_1 to be set sufficiently high such that the fringe is more that compensated for the difference should area *fgji* exceed area *abfe*, but not so high that the dominant firm loses all of area *cdhg*. As long as the total gain from retiring quota exceeds the total cost, there must exist an R_1 such that the trade is possible.

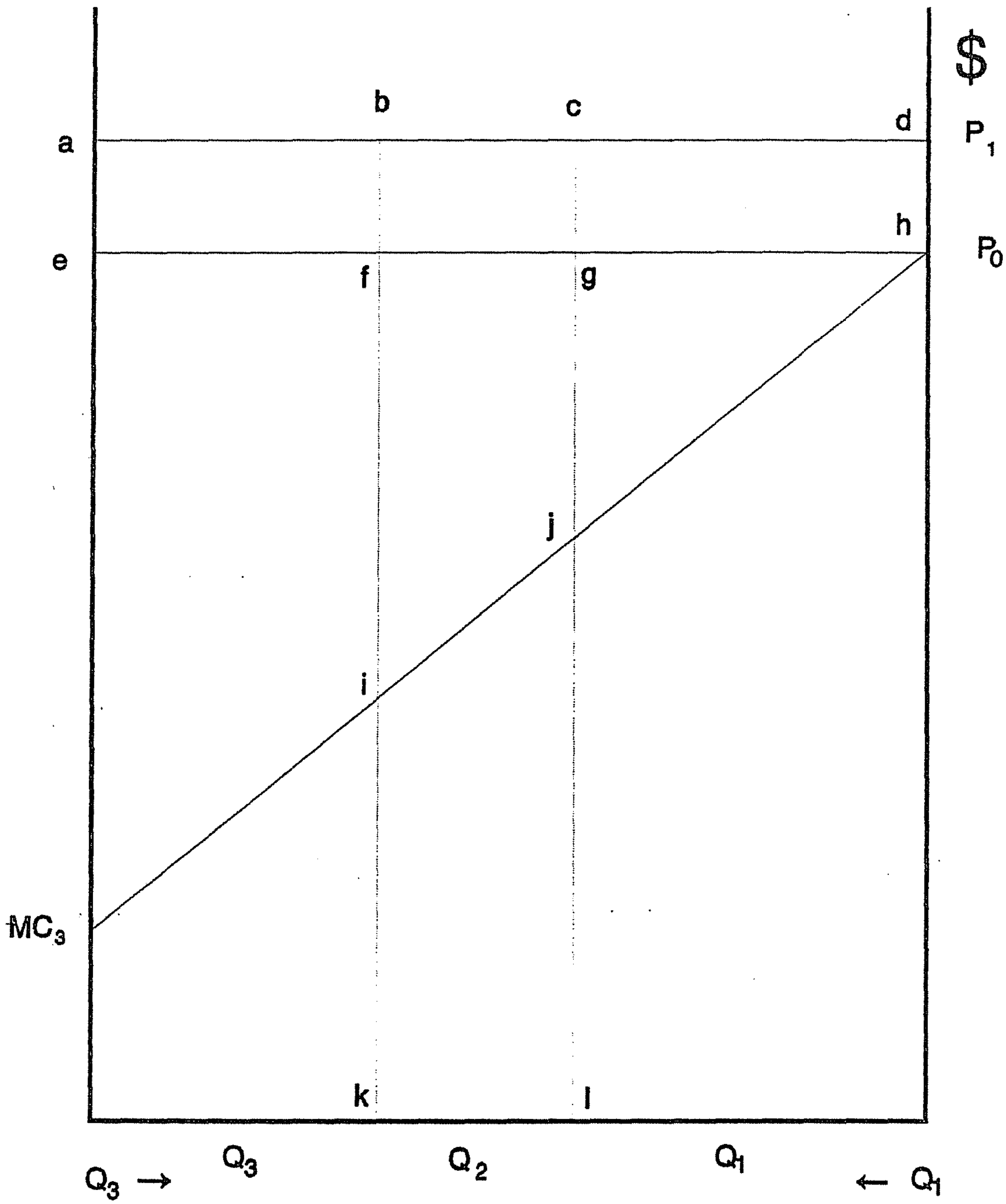

Figure 4. Realizing the profits from retiring quota

The deal's success does not depend upon the dominant firm already owning Q_1. If it profits the dominant firm to buy Q_1 to fish, then its total cost of fishing Q_1 must be less than what it would cost the fringe to fish Q_1. It thus follows that there must exist an R_1 which the dominant firm can offer for $(Q_1+Q_2)/n$ quota from each firm, conditional upon all fringe firms agreeing to sell, that ensures that all parties profit from agreeing to the trade.

Allowing For Stock Effects

Anderson's analysis also ignores stock effects. Retiring quota will not only raise fish prices but will also likely lower fishing costs as stocks increase owing to the lower harvest (Anderson, 1977: 66-67). The equilibrium condition for the competitive fringe when there are stock effects is

$$\overline{P}(Q_2) - MC_3(Q_3, X(Q_2)) = R, \tag{20}$$

where $X(Q_2)$ is the stock of fish and $\partial X/\partial Q_2 > 0$. The supply price of quota is now

$$R(Q_1,Q_2) = \overline{P}(Q_2) - MC_3(\overline{Q} - Q_1 - Q_2,\ X(Q_2)). \tag{21}$$

Differentiating with respect to Q_1 and Q_2 yields

$$\frac{\partial R}{\partial Q_1} = -\frac{\overset{(-)}{\partial MC_3}}{\partial Q_1} > 0, \tag{22}$$

and

$$\frac{\partial R}{\partial Q_2} = \overset{(+)}{\frac{dP}{dQ_2}} - \overset{(-)}{\frac{\partial MC_3}{\partial Q_2}} - \overset{(-)}{\frac{\partial MC_3}{\partial X}}\frac{dX}{dQ_2} > 0. \tag{23}$$

The quota price, R, is increased by buying and retiring quota first by the effect on fish price, second by the effect of moving along the fringe's marginal cost curve, and now third by lowering the fringe's marginal cost curve through the improvement made to fish stocks.

Now consider the dominant firm's profit function when it begins with no quota

$$\pi = \overline{P}(Q_2)Q_1 - TC_1(Q_1, X(Q_2)) - R(Q_1, Q_2)[Q_1 + Q_2]. \tag{24}$$

The first-order condition with respect to Q_2 is

$$\frac{\partial \pi}{\partial Q_2} = \frac{d\overline{P}}{dQ_2}Q_1 - \frac{\partial TC_1}{\partial X}\frac{dX}{dQ_2} - \frac{\partial R}{\partial Q_2}[Q_1 + Q_2] - R = 0. \tag{25}$$

The gain to the firm of buying and retiring Q_2 at the margin is the increase in fish price multiplied by its catch plus the reduction in total costs. It is this marginal gain that the dominant firm equates to the marginal factor cost of quota.

Substituting from equation (23), equation (25) becomes

$$\frac{d\overline{P}}{dQ_2}Q_1 - \frac{d\overline{P}}{dQ_2}Q_1 - \frac{\partial TC_1}{\partial X}\frac{dX}{dQ_2} + \frac{\partial MC_3}{\partial Q_2}[Q_1 + Q_2] + \frac{\partial MC_3}{\partial X}\frac{dX}{dQ_2}[Q_1 + Q_2] - \frac{\partial \overline{P}}{\partial Q_2}Q_2 - R = 0. \tag{26}$$

The first two terms cancel as before but the next term, the reduction in the dominant firm's total cost owing to the retiring of additional Q_2, is positive. It may now be profitable for the dominant firm to buy and retire quota. However, the stock-effect alone is not sufficient. The reduction in the dominant firm's total cost must exceed the reduction in the fringe's marginal cost multiplied by the amount of quota the dominant firm buys plus the gain in fish price multiplied by the amount of quota the dominant firm retires plus the market price of quota. The key to deriving this result is that the stock effect must affect the dominant firm's and the fringe's costs differently. Such a difference in effect may not be so unlikely because the dominant firm by definition must have some cost advantage over the fringe and hence a different fishing technique.

The result is shown in Figure 5. The reduction in marginal costs increases the fringe's marginal willingness-to-pay for quota to R_3''. The dominant firm buys Q_1 and Q_2 and retires Q_2. The firm's gain from retiring Q_2 is area *abdc* plus area *hij* — the firm's reduction in total cost. If area *hij* is sufficiently large such that these two areas are greater than *eR''Rkgf*, the cost of buying and retiring Q_2, then it is indeed profitable to buy and retire Q_2. Figure 5 explains how the profitability of buying and retiring Q_2 depends upon the relative effects on the fringe's marginal cost and the dominant firm's total cost.

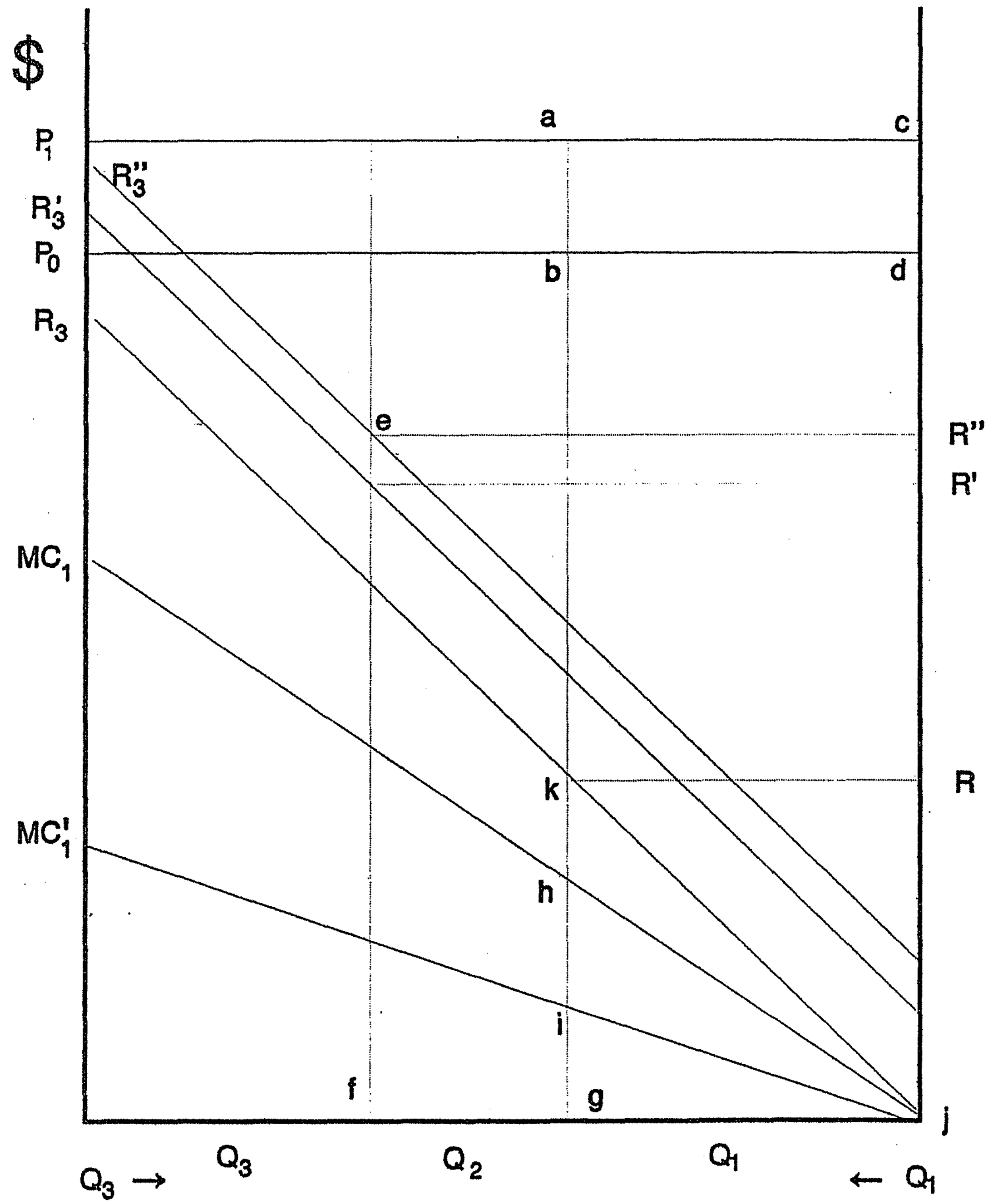

Figure 5. Including stock effects

NEW ZEALAND'S EXPERIENCE

The possibility of monopolization with ITQs cannot be dismissed theoretically as Anderson concludes. Whether or not firms find it profitable to raise fish prices by buying and retiring quota remains an empirical question. Moreover, it may prove profitable to retire quota simply to improve fish stocks and so lower fishing costs.

The Puzzle of Uncaught Quota

In this latter regard, the experience in New Zealand is interesting. ITQs were introduced there in 1986.[1] The 31 species or species groupings under the scheme are divided into different Quota Management Areas (QMAs). There are thus several fisheries for each species or species group. Pooling the available data over five years of observation provides 678 fishery-years. Twenty-five percent or more of the quota allocated remained uncaught in 316 of these 678 fishery-years. Moreover, the reported average trade price of quota equalled or exceeded $NZ1,000 a tonne in 206 of these 316 fishery-years. The positive price of quota in

1. For details on the introduction and operation of the ITQ system in New Zealand, see Clark, Major and Mollett (1988).

conjunction with quota remaining uncaught is consistent with firms retiring quota to raise fish prices and/or improve fish stocks.

However, the ability of New Zealand firms to raise fish prices appears very limited — most of the catch is exported. In 1989 87% of the total catch by value was exported, with Japan, the United States and Australia accounting for 81.5% of the export trade (NZFIB 1990: 8,15). It seems very unlikely that a fishing firm could increase fish prices in these markets by retiring quota in New Zealand.

Notwithstanding the fishing industry's export orientation, quota aggregation was a worry for New Zealand legislators. The legislation implementing ITQs requires that a firm receive express Ministerial permission to hold more than 35% of total quota for listed deepwater species or more than 20% of the quota in any QMA for all other species.[2]

There has, however, been no tendency for quota to concentrate. The Herfindahl Index calculated for quota share first by species and second by fishery for each fishing year beginning 1 October 1987 shows no evident

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2. *Fisheries Amendment Act 1986*, s. 28W.

trend.[3] The lack of a trend rules out the possibility that large firms are systematically buying quota to retire.

The Possibility of Stock Effects

One possible explanation for quota remaining uncaught yet still fetching a good price is that firms are retiring quota they already own to improve stocks and so lower their costs. Consider the case of a firm already owning quota and contemplating retiring quota to improve fish stocks. Let $\bar{Q}$ equal the total quota allocated, Q the total catch, Q_I the quantity of quota owned by the firm, and Q_R the quota it retires. The total catch, Q, is given as follows

(27) $$Q = \bar{Q} - Q_R.$$

The firm's profit is

(28) $$\pi = [P - AC(Q)](Q_I - Q_R).$$

Fish price is given but average cost, *AC(Q)*, is a function of total catch and hence of Q_R — the quota the firm retires. Notice that the firm's gain from retiring quota is made only on the quota it fishes. The assumption is that the other

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3. The Herfindahl Index is calculated as follows. Let q_i equal the *ith* firm's share of total quota allocated in the fishery. The Herfindahl Index is given as follows

$$Herf = \sum_{i=1}^{n} q_i^2$$

where n equals the number of firms in the fishery. The Herfindahl Index must lie between 0 and 1, and the higher the Index, the more concentrated the ownership of quota.

firms holding quota, and who benefit from the first firm's decision to retire quota, do not contract with the first firm and so retire quota to maximize total profits. The firm's decisions to retire quota thus generates a positive externality. Differentiating equation (28) with respect to Q_R yields the first-order condition

$$\pi_{Q_R} = \frac{\partial AC}{\partial Q}[Q_I - Q_R] - [P - AC(Q)] = 0. \quad (29)$$

The firm retires quota until marginal gain just equals marginal cost. Assuming that the implicit function theorem holds, equation (29) can be solved for Q_R^* — the optimal amount of quota for the firm to retire

$$Q_R^* = f(\frac{\partial AC}{\partial Q}, Q_I, P, AC). \quad (30)$$

The amount of quota the firm retires is a function of the effect retiring quota has on cost, the quota the firm holds, the price of fish and fishing cost.

More specifically, the effect of quota owned on quantity retired can be signed. The Envelope Theorem provides the following result (Silberberg, 1990: 197)

$$\pi_{Q_R Q_I} \frac{\partial Q_R^*}{\partial Q_I} > 0. \quad (31)$$

Differentiating equation (38) with respect to Q_I yields

$$\pi_{Q_R Q_I} = \frac{\partial AC}{\partial Q}. \quad (32)$$

The sign of equation (41) will be positive if there is any stock effect and thus $\partial Q_R{*}/\partial Q_I$ from equation (40) must also be positive. That is, the more quota the firm owns, the more it will retire, all things being equal.

The result is illustrated in Figure 6 below.

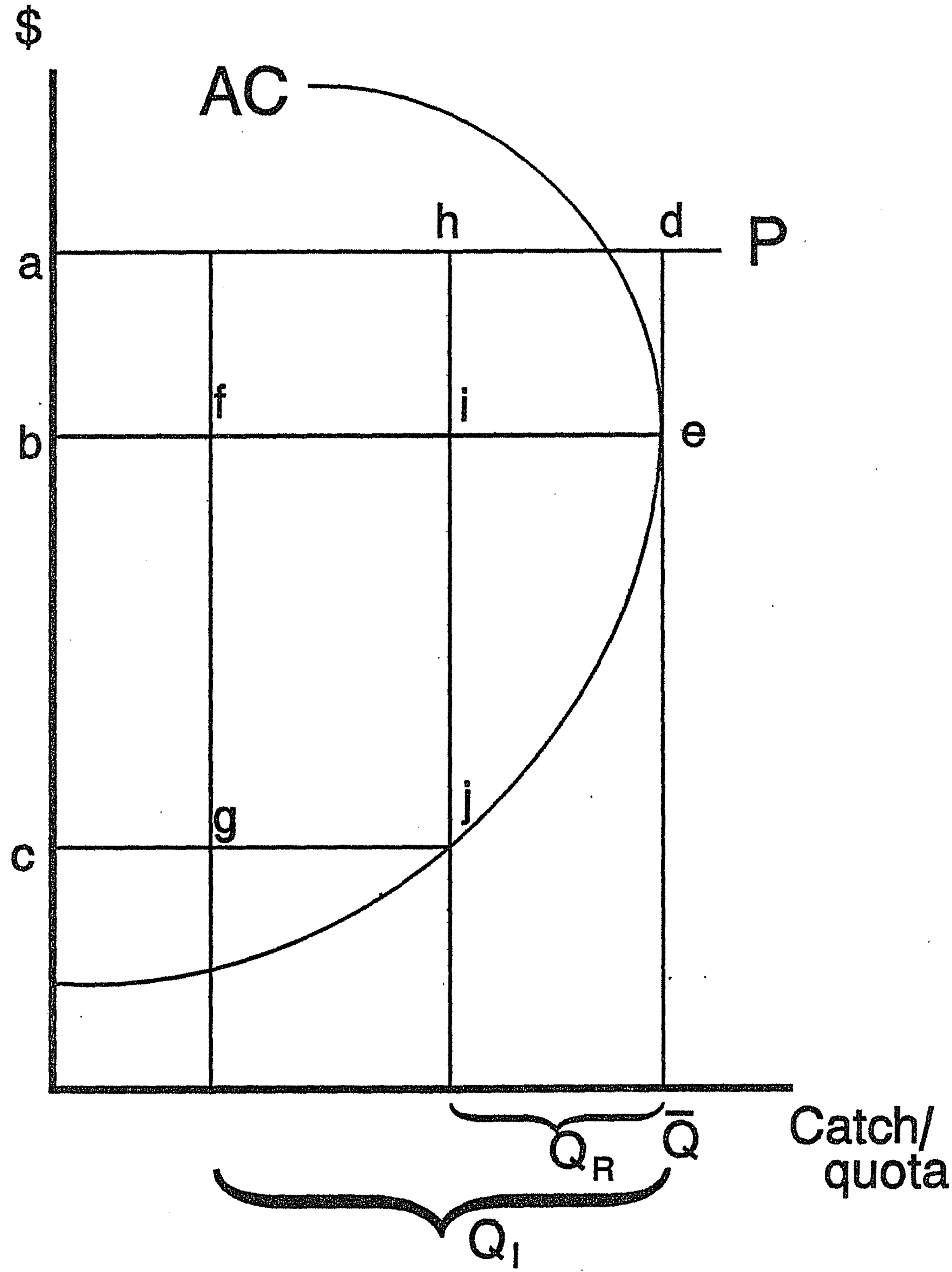

Figure 6. The decision to retire quota

Figure 6 shows the usual backward-bending average cost curve associated with the underlying population growth function. Assume the total quota, $\bar{Q}$, is set at Maximum Sustained Yield. The total fishery now yields a rent of area *adeb*. If the major quota holder retires Q_R, the total rent goes up by area *bijc* minus area *hdei*. However, the major quota holder's share of the gain is only area *fijg* whereas the entire cost of retiring quota, area *hdei*, falls to him. The magnitude of the positive externality in total is area *bfgc*. Clearly, the more quota the firm owns, the greater is its marginal gain from retiring quota, and hence the more quota it will retire, all other things equal. This result assumes no contracting between the major quota holder and the smaller quota holders who enjoy the benefit from retired quota but who pay none of the cost.

Econometric Model

The result so derived immediately suggests a testable implication: the percentage of quota uncaught should correlate with quota concentration. All things being equal, the more the quota is concentrated, the more quota should be left uncaught. Accordingly, the following regression was run

$$Percentleft = a + b_1 Herfindahl + b_2 Fish\,price + b_3 Cost + \sum_{i=2}^{S} b_{4i} Species_i + e \qquad (33)$$

$$S = 29.$$

The percent left was calculated for each fishery as the difference between total catch and the total quota held for each year. Quota held is not the same as quota owned as the New Zealand government owns quota which it does not fish but which it leases and which appears as quota a firm holds. The Herfindahl Index was calculated for each fishery stock for each year on quota owned. The quota owned by the government was excluded from this calculation. Fish price is the indicative port price reported by the New Zealand Fishing Industry Board each year. Not all prices are reported for each year and those species without a price for the year in question were eliminated. No prices were reported for two species (Rock Lobster and Packhouse Lobster) and they were eliminated. A cost index for hunting and fishing reported by the New Zealand Department of Statistics was used for cost. A species dummy was also used in the regression to capture any species-specific effects such as the effect retiring quota has on fishing cost.

The regression should ideally be run as a simultaneous system with cost a function of percent left. Unfortunately, the only available data on cost is a cost index. As a result, cost is included in the regression to account for the effect of any general change in fishing costs from year to year. If the costs of fishing rise, then more quota will be retired all things being equal. An increase in the cost of fishing reduces the opportunity cost of retiring quota.

Regression Results and Interpretation

The results of the regression along with summary statistics are reported in Tables 1 and 2. The percent left correlates strongly with quota concentration with the relationship a quadratic one. The percent left thus increases with quota concentration, all other things equal, with the effect lessening as concentration increases. The result also shows that the percent overfished also decreases with higher quota concentration, all other things being equal.

Table 1. Summary statistics of major regression variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Percent Left	38.553	27.892	0.1	100
Herfindahl	0.14901	0.13996	0.01958	1
Fish Price	1712.7	2778.4	100	35000
Cost	1387.0	53.945	1337.0	1494

n = 449

Table 2. Main regression results

Variable	Coefficient	t-ratio
Constant	21.222	0.75
Herfindahl	182.84	7.87
Herfindahl^2	-107.21	-3.71
Fish price	0.00035	-0.44
Cost	-0.013	-0.65
Blue Cod	36.28	4.72
Bluenose	-8.74	-1.02
Alfonsino	-5.75	0.66
Elephant fish	12.32	1.47
Flatfish	29.47	3.43
Grey Mullet	2.26	0.25
Gurnard	15.42	1.97
Hake	4.91	0.51
Hoki	-5.70	-0.41
Hapuku/Bass	17.59	2.38
John Dory	11.63	0.91
Jack Mackerel	-1.48	-0.10
Ling	17.63	2.34
Moki	51.16	5.35
Oreo Dory	9.97	1.17
Orange Roughy	-18.28	-2.09
Paua	-4.90	-0.29
Red Cod	43.61	5.53
School Shark	6.42	0.86
Gemfish	-5.27	-0.64
Snapper	-0.56	-0.06
Rig	7.24	0.88
Squid	31.85	2.75
Stargazer	8.06	0.95
Silver Warehou	-9.99	-0.97
Tarakihi	0.26	0.03
Trevally	-3.16	-0.37
Blue Warehou	28.91	3.85

Excluded dummy: Barracouta

R-Square = 0.4266   416 DF

The relationship between quota concentration and percent left also holds when those fisheries that were overfished by up to 100% are included in the regression. The relationship is also found to be a robust one. The same regression was run eliminating the very concentrated fisheries (Herfindahl > 0.7), and all fisheries apart from the five major species by value (Hoki, Orange Roughy, Paua, Snapper and Squid), and in each case quota concentration remained correlated with percent left. The results of these regressions are reported in the Appendix.

However, the result provides only indirect evidence that quota is being retired to improve fish stocks. At best the result is consistent with the hypothesis that quota is being left uncaught so as to lower fishing costs.

Other explanations on why quota remains uncaught have been offered. Annala *et al.* (1991) suggest that quota is left uncaught because it is proving uneconomic to fish some fisheries to maximum sustained yield and also that quota on by-catch fisheries becomes binding before the quota for the target species is caught. The problem with both explanations is why quota trades at such a high price even when substantial amounts remain uncaught. Fishing is an uncertain business and the high price of quota may simply represent the insurance value of additional quota. However, both explanations fail to explain the strong correlation between quota concentration and the amount left uncaught.

Another possible explanation consistent with the observed relationship is that higher quota concentration also means higher marginal returns for a firm lobbying to have a total allowable catch (TAC) increased so that quota prove less of a constraint. Once again, fishing is an uncertain business and it may be of value to firms to have higher TACs even when substantial amount of quota remains uncaught. Clearly further work is needed before the puzzle of the uncaught quota is fully resolved. At the very least it would be interesting to obtain the catch records of individual quota holders and determine whether it is indeed the large quota holders who are leaving quota uncaught.

CONCLUSION

The following conclusions may be drawn from the foregoing study. First, the worry that ITQs will allow a firm or firms to achieve market power in fish markets cannot be dismissed theoretically. The conclusion that it will never prove profitable to achieve market power by buying ITQs depends critically upon assumptions that ensure that any of the gain that a firm achieves through market power is more than offset in the higher price it must pay for the quota it fishes and thus from which it profits. Relaxing the assumptions necessary to derive this result shows that a firm may well find it profitable to buy into a monopoly following the introduction of ITQs.

Second, although the data from New Zealand show no tendency for quota to concentrate, considerable quota remains uncaught and this same quota is trading oftentimes for a good price. With their heavy orientation towards overseas markets, New Zealand fishing firms appear to have little ability to raise prices by retiring quota. The amount of quota left uncaught nonetheless correlates strongly and positively with quota concentration. This result is at least consistent with the hypothesis that firms are retiring quota so as to improve stocks and so lower fishing costs. The more quota a firm has, the higher its marginal gain from retiring quota, and so the more quota it will retire, all other things equal.

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APPENDIX

Table 3. Results of regression that includes overfished fisheries

Variable	Coefficient	t-ratio
Constant	85.01	2.64
Herfindahl	209.46	7.30
$Herfindahl^2$	-107.67	-2.90
Fish price	0.00034	-0.52
Cost	-0.07	-2.99
Blue Cod	46.68	4.97
Bluenose	-11.60	-1.17
Alfonsino	-15.06	-1.49
Elephant fish	8.37	0.85
Flatfish	42.40	3.96
Grey Mullet	7.50	0.65
Gurnard	16.81	1.78
Hake	6.86	0.59
Hoki	-9.12	-0.60
Hapuku/Bass	28.65	3.21
John Dory	19.32	1.15
Jack Mackerel	-4.02	-0.24
Ling	10.54	1.20
Moki	12.01	1.15
Oreo Dory	-1.00	-0.10
Orange Roughy	-21.83	-2.39
Paua	0.84	0.05
Red Cod	53.56	5.42
School Shark	11.83	1.33
Gemfish	-13.29	-1.34
Snapper	-3.60	-0.37
Rig	12.28	1.28
Squid	12.35	0.96
Stargazer	-10.75	-1.20
Silver Warehou	-34.31	-3.25
Tarakihi	-5.15	-0.59
Trevally	-8.32	-0.82
Blue Warehou	37.97	4.06

Excluded dummy: Barracouta

R-Square = 0.3626 566 DF

Table 4. Results of regression with very concentrated fisheries (Herfindahl > 0.7) eliminated

Variable	Coefficient	t-ratio
Constant	26.31	0.92
Herfindahl	226.11	5.62
$Herfindahl^2$	-226.53	-2.92
Fish price	0.00053	0.66
Cost	-0.02	-0.96
Blue Cod	38.02	4.86
Bluenose	-5.85	-0.68
Alfonsino	8.07	0.89
Elephant fish	14.29	1.67
Flatfish	31.31	3.58
Grey Mullet	-2.19	-0.22
Gurnard	16.23	2.08
Hake	4.76	0.50
Hoki	-5.58	-0.40
Hapuku/Bass	18.33	2.48
John Dory	11.11	0.88
Jack Mackerel	-1.51	-0.11
Ling	18.36	2.46
Moki	51.99	5.46
Oreo Dory	6.95	-0.79
Orange Roughy	-18.42	-2.13
Paua	-4.26	-0.24
Red Cod	44.73	5.67
School Shark	7.56	1.00
Gemfish	-4.14	-0.51
Snapper	0.40	0.05
Rig	8.77	1.06
Squid	32.40	2.82
Stargazer	9.59	1.14
Silver Warehou	-10.28	-1.01
Tarakihi	0.08	0.01
Trevally	-3.20	-0.37
Blue Warehou	29.25	3.92

Excluded dummy: Barracouta

R-Square = 0.3813   404 DF

Table 5. Results of regression with 5 major species only

Variable	Coefficient	t-ratio
Constant	68.19	0.88
Herfindahl	159.22	6.36
Fish price	-0.00019	-0.316
Cost	-0.058	-0.06
Orange Roughy	-12.65	-0.97
Paua	3.51	0.20
Snapper	4.24	0.31
Squid	20.39	1.32

Excluded dummy: Hoki

R-Square = 0.3780 81 DF