RENT CAPTURE IN RIGHTS BASED FISHERIES

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Abstract

A major issue in resource economics is the capture of economic rent. In fisheries, in contrast to nonrenewable resources, there has been a general failure by regulators to prevent rent dissipation or capture rent where it exists. New ways of managing fisheries such as the assignment of property rights in the form of individual harvesting rights have been introduced in Canada and other countries and have proved successful in improving economic efficiency. Despite such success, there remains no detailed study of the implications of rent capture from such fisheries. The thesis addresses this important problem in both a theoretical and empirical framework.

The theoretical model assumes a fishery regulated by an individual transferable quota scheme where there are two representative fishers that differ only with respect to their harvesting functions and fixed costs. The short-run quota equilibrium in the fishery is compared to a first-best solution where a resource owner can determine the number of fishers of each type, their individual harvests, and the biomass. Assuming risk averse behaviour by fishers, it is shown that with uncertainty the expected rent in the fishery will be equal to or less than the equilibrium with no uncertainty. Such a result is not the case in an open access fishery. An implication of the work is that reducing the uncertainty faced by all fishers for a given total allowable catch will not decrease the expected rent from the fishery and in general will increase it. Decreasing the risk costs of certain fishers and not others may, however, increase or decrease the expected rents.

Using the theoretical model, different methods of rent capture including a quota rental charge, profit charge, net cash flow charge, *ad valorem* royalty, auction of
the harvesting rights, lump sum fee, and a quota transfer charge are compared and evaluated. The criteria for assessing the different methods of rent capture include their effect upon the profits of different fishers, efficiency, costs of rent collection, and risk sharing and flexibility. It is shown that with no uncertainty a quota transfer charge and lump sum fee are both capable of distorting the Pareto efficient quota equilibrium while still capturing less than the estimated resource rent. Assuming variability in the output price, it is shown that a profit charge, net cash flow charge, and an *ad valorem* royalty cannot decrease and will in general increase the expected rent at any charge rate whenever the quota price is positive. Comparisons between the rent capture schemes also reveals differences in the burden of the rental paid by different fishers.

The empirical study examines the effects of rent capture in a rights based fishery using data from the British Columbia sablefish fishery. The first part of the study estimates the rent in the fishery using a 1988 costs and earnings survey of individual fishers. Estimates of the rent in 1990 are obtained from simulations using a normalised quadratic and a translog restricted profit function. Using the simulations, the different methods of rent capture are examined with respect to the burden they impose on fishers and implications for the fishery.

The thesis provides several contributions to the literature. It provides an original framework for examining different methods of rent capture in a rights based fishery with heterogeneous fishers with and without uncertainty. Using this model, the thesis distinguishes between short and long-run phenomena and presents the important differences between the several methods of rent capture. Using data from the British Columbia sablefish fishery, the thesis also provides the first empirical study of the effects of rent capture in a rights based fishery.
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Chapter 1

The Problem, Objectives, Literature Review, and Overview

The land is the principal of the natural agents which are capable of being appropriated, and the consideration paid for its use is called rent.


1.1 The Problem

It has long been recognised that in an open-access fishery [Warming (1911), Gordon (1954), and Scott (1955)] there may arise a divergence between private and social costs such that total fishing effort exceeds the level that maximises the net returns in the fishery. The externality arises from the fact that one fishing vessel’s harvest reduces the total stock available to other vessels which in turn can increase their harvesting costs. In Gordon’s static analysis, the open-access fishery tends to reach a bionomic equilibrium where the total fishing cost equals total revenue. A level of fishing effort below the equilibrium would mean fishers were earning above normal profits and in a competitive environment would attract additional fishing effort. A level of fishing effort above the equilibrium would mean total costs exceed total revenue such that some fishers would be obliged to leave the fishery. The result is the dissipation of the potential rents from the fishery and excessive depletion of the resource.

In regulated fisheries, the externalities evident in an open-access fishery may continue to exist where there are controls on the total harvest but there are ineffective
restrictions upon fishing effort. In such fisheries, the incentive remains for fishers to compete for the limited harvests leading to excess effort and capacity above that necessary to harvest the total allowable catch (TAC). In turn, excess fleet capacity may also result in a crowding externalities whereby fishers impede each others harvesting efforts.\footnote{A review of the externalities prevalent in fisheries including stock, crowding, and mesh externalities is given by Smith (1969).} The result, with or without crowding externalities, is again the dissipation of potential rents [Munro and Scott (1985), 657-664].

A type of management that attempts to improve economic efficiency and reduce the externality problem in fisheries is the assignment of property rights to harvesters of the resource [Scott (1986)]. These property rights may take the form of output controls such as territorial user rights in fisheries (TURFs) and individual transferable quotas (ITQs). The assignment of such rights may be defined as rights based fisheries management. In the case of TURFs, resource users are assigned harvesting rights to specific locales. For sedentary species [Beddington and Rettig (1984)] and where TURFs are exclusive and enforceable, fishers can operate more as sole owners rather than competitive harvesters of the resource. In turn, this can reduce harvesting costs and increase the net returns from the fishery.

Improvement in efficiency may also arise with the use of ITQ's which allocate a total allowable catch (TAC) among fishers in the form of individual harvesting rights. By providing fishers with a greater assurance of harvesting a certain share of the resource, such quotas may reduce racing behaviour between fishers to "catch the fish before someone else does" and allow quota-holders to harvest the resource in a less costly manner. Evidence from Australia [Geen and Nayar (1989)] and Canada [Crowley and Palsson (1990)] suggest that ITQs and rights based management have indeed improved economic efficiency in fisheries. Rights based management has also
been successfully introduced into several other countries. Such management is evident in Canada's Pacific [Canada Fisheries and Oceans (1990a)] and Atlantic fisheries [Fraser and Jones (1989), Gardner (1989)], in Iceland [Arnason (1986)], in some of the commercial fisheries of the Great Lakes, Australia's southern blue fin tuna fishery [Geen and Nayar (1989)], and in most of the coastal and offshore fisheries of New Zealand [Clark et al. (1989), Muse and Schelle (1988)]. Rights based management in the form of ITQ's can, however, create new problems for resource owners. A review of these issues is provided in Copes (1986).

Allowing transferability of quota can also enable more efficient operators to acquire a greater share of the total harvest. By setting a TAC in a quota management system such that harvesting rights are scarce, the resource owner can allow for the existence of a resource or scarcity rent. This rent, which reflects the difference between the output price and marginal cost of production, should be reflected in the market price of quota. In the case where quota is allocated gratis to fishers and there is no attempt to collect the resource rent, returns in excess of normal profits accrue to the first generation of quota-holders. Where, however, the resource owner wishes to capture a share of this rent there is little guidance available on the consequences of rent collection. Despite a great deal of literature on the subject of rent capture in nonrenewable resources, there are very few papers [Waugh (1987), Grafton (1992)] that compare different methods of rent capture in fisheries. To date, there has also been no empirical investigation that compares different methods of rent capture in rights based fisheries.

The problem of how one may capture resource rent from a rights based fishery and the consequences of different methods of rent capture is examined in the following chapters. The contribution of this work is two-fold. First, it addresses an important issue in resource economics that has received little attention. Second, the implications
of rent capture in both a theoretical and empirical framework may aid resource owners in the practical collection of rent. Given that rights based management is now being introduced into fisheries on a world-wide basis, this has become an important policy issue.

1.2 Objectives

The principal objective of the thesis is to evaluate several systems of rent collection in a theoretical and empirical framework so as to rank different methods of rent capture under different criteria and circumstances.

The conceptual framework in chapter 3 provides the basis for studying a number of rent capture methods in a hypothetical fishery regulated with individual quotas. The theoretical environment is that of a fishery where management is vested in a regulator. In place in the fishery is an ITQ management scheme, where quota was originally allocated gratis to fishers, trades at a positive price and is denominated in quantity of fish that may be harvested per unit of time. Initially operating in the fishery are two types of fishers each maximising their expected utility of economic profits and who differ only with respect to their fixed costs of production and harvesting technology. Using this framework, the effects of uncertainty on the quota equilibrium and expected rent in the fishery are examined. A comparison is also made between the short-run quota equilibrium and a first-best situation.

Using the conceptual framework, chapter 4 examines several methods of rent capture with respect to their effect upon the profits of fishers, distortions imposed upon the fishery, costs of rent collection, and risk sharing and flexibility. Using the specified criteria, each of the methods of rent capture is given a relative ranking under each item. No attempt is made to construct a criterion or social welfare function of
fishers under the different rent collection devices. Use of such a device would require attaching weights to an objective function that would vary according to the resource owner and the specific conditions in a fishery. The rent capture schemes examined in the thesis include:

- Quota rental charge based on the market price of quota in leases and/or sales.
- Profit charge on a proportion of the pre-tax net revenue of fishers.
- Net cash flow charge.
- *Ad valorem* royalty based upon quota-holdings and the landed price of fish.
- Lump sum fee/charge.
- Auction of individual quotas valid for a given period of time.
- Quota transaction charge payable whenever quota is traded.

These methods of rent capture do not exhaust the possible choices available to a resource owner but are a selection that have been proposed in fisheries or applied elsewhere. In particular, a profit tax is a common approach in taxing individuals and enterprises, a net cash flow charge has been proposed in some of Australia’s commonwealth fisheries [Campbell and Haynes (1990)], an auction is a common method of capturing rents in exhaustible resources, a lump sum or fixed fee charge is a usual method of charging fishers to help cover regulatory costs, a quota rental charge is a natural method of capturing rent from ITQ fisheries, and an *ad valorem* royalty has been proposed as a means of correcting externalities in open-access fisheries.

The empirical study in chapters 5 and 6 is complementary to the theoretical analysis and compares different methods of rent capture in the British Columbia
Chapter 1. The Problem, Objectives, Literature Review, and Overview

(BC) sablefish fishery. This fishery has been managed with a licensing system since 1981 which restricted the gear used by fishers and the total number of vessels to 48. Since 1990, the fishery has been managed with a form of ITQ’s called individual vessel quotas (IVQ’s). This management system was implemented for an initial two year trial period with the support of fishers in the industry. The IVQ’s were assigned gratis to fishers on the basis of past catches and vessel length, denominated as a proportion of the TAC, and made transferable only among licence-holders for amounts no less than the initial quota allocations [Canada Department of Fisheries and Oceans (1990b)].

The purpose of the empirical study is to address the problem of rent capture in an actual fisheries environment. Such a study is necessary because there are insights and implications that can be obtained from a specific fishery that may not be possible in a theoretical framework.

1.3 Review of the Literature

Much has been written on the issue of rent and its capture. Some of the earliest writings on the subject are proposals to capture ground rent from land by John Stuart Mill (1848) and Henry George (1879). Other notable economists who proposed capturing land rent include both Walras and Wicksteed [Blaug (1986), 85].

Today, the issue of rent capture refers to more than just land but can include all renewable and nonrenewable resources. The major issues addressed include efficiency, or how to extract rent with the least distortion possible to optimising behaviour, and equity, or the effect on the after-tax distribution of net returns [Garnaut and Ross (1979), Boadway and Flatters (1983), and Conrad and Gillis (1985)]. In the general

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2The sablefish is commonly known as the black cod although it is not a member of the cod family. It is known scientifically as, Anoploma fimbria, and is an important commercial species found in waters from Bristol Bay, Alaska to southern California.
taxation literature, the concepts of equity are divided into horizontal equity (the burden of tax across individuals of the same means) and vertical equity (the burden of tax across individuals of different means).\(^3\)

In measuring efficiency and rent capture from resources, the concept of neutrality is often applied with the usual assumption that the rest of the economy is fully competitive and efficient. In particular, a tax is preferred over another if, *ceteris paribus*, it distorts the extraction or production profile the least. A neutral tax is one that leaves the rent maximising production profile unchanged. In this vein, Slade (1986) has examined resource taxation in exhaustible resources at different stages of production and from the policy goals of neutrality, increased conservation, and accelerated depletion. Slade observes that with a tax imposed where there is resource processing after extraction and before sale of the commodity, that tax will depend upon all parameters of the processing technology. In a nonhomogeneous industry, therefore, a tax that is neutral on an industry basis cannot be neutral for every firm.

Other issues with respect to efficiency and rent capture include the tilting of output over time, effects on exploration, optimal mix of factors, and efficiency of factor utilisation [Heaps and Helliwell (1985)]. A consideration of both equity and efficiency issues in the mining industry is provided by Church (1982). The subject of rent capture and its effect on exploration and efficiency of factor utilisation is examined by Garnaut and Ross (1975). In particular, they note that “... maximising total government revenue involves balancing the possibility of revenue loss on highly profitable projects ... against the possibility of setting rent charges so high that there is revenue loss through deterrence of projects which, *ex ante*, are not certainly intra-marginal.” [Garnaut and Ross (1975), 273] A consideration of this issue and questions of *ex-ante* and *ex-post* rent capture and the nature of the rent itself is given.

\(^3\)Slemrod (1990) provides a review of taxation and tax systems in the general tax literature.
by Grubel (1979) and Cairns (1977, 1980). Garnaut and Ross also address the issue that higher marginal tax rates reduce the incentive for efficiency thereby reducing the rent available to be captured and examine the uncertainty that ex post adjustments in taxation place on firms undertaking investment decisions. In consideration of these factors, they propose a Resource Rent Tax (RRT) that is like a profit tax but includes exploration costs as an expense and only collects rent after a certain threshold on an internal rate of return on total cash flow has been achieved.

Comparisons of different methods of rent capture in exhaustible resources has also been important in the literature. A review of different methods of rent capture that may be applied is provided by Heaps and Helliwell (1985). They include gross royalties based on either output or value, net royalties based on profits, taxes based on hypothetical costs for a given class of operation, equity participation by the resource owner, property taxes based upon the total value of the resource, and auction or tendering of exploration or development rights. A well known result is that a gross royalty does distort the production profile of a mine in that the higher the tax rate the higher the 'cut-off' grade of ore left in the ground.4 A comparison of the efficiency effects of a gross royalty compared to a profit tax is provided by Bradley et al. (1981). They find that in the BC copper mining industry the efficiency of a gross royalty is conditioned on the tax rate.

In the Canadian context, rent capture in overall tax policy is reviewed by Boadway and Kitchen (1980). The political economy of resource rents and a review of the methods and consequences of rent collection in Western Canada is provided by Gunton and Richards (1987). A summary of the major issues of mineral taxation in Canada is given by Parsons (1982).

In contrast to nonrenewable resources, there has been very little published on the

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4Neher (1990), chapter 19 discusses the effects of a gross royalty, profit tax, and RRT.
subject of rent capture in fisheries. Much of the work has focussed upon ways of overcoming the externality problem and avoiding rent dissipation in both open access and regulated environments. On this issue, Crutchfield and Pontecorvo (1969), Flagg (1977) and Dupont (1988, 1990) among others have quantified the problems of rent dissipation in various fisheries. In particular, Dupont (1990) showed that a restrictive licensing policy and government determined total catch in the BC salmon industry has led to substantial dissipation of the potential rents. Schwindt (1987) provides a review of the public policy and issue of rent in the same industry. He notes that a buy-back scheme of vessels would reduce the overcapitalisation problem but without rent capture by the crown further rent dissipation would take place. De Voretz and Schwindt (1985) also provide estimates of rent in Canada’s Pacific fisheries. In particular, they examine the possible effects of a license auction scheme and royalties on catches in the salmon industry.

The question of capturing resource rents in fisheries has received much less attention. The literature on taxation deals almost exclusively with the issue of controlling fishing effort. In particular, Clark (1985) and others have examined a royalty or landing tax on fish which can reduce fishing effort by reducing the net price of fish to fishers. In this respect, Clark (1990, 256-260) has demonstrated that ITQ’s can be equivalent to a single landings tax in terms of economic efficiency but not in terms of distribution of returns. This equivalency will arise if fishers have identical harvesting functions and if the TAC under ITQ management is set such that the annual market price of quota equals the given landings tax. In actuality, fishers do differ in their harvesting functions and the information requirements necessary to optimise the level of fishing effort with landing taxes is beyond the capacity of most fishery managers. Recognising this problem, Arnason (1989) has recommended a minimum
information management scheme that uses ITQ's. He shows that under certain assumptions and using ITQ's allocated as a percentage or share of the TAC, the fishery manager can maximise the net returns from the fishery. This results from judicious adjustments in the TAC by the manager such that the market value of outstanding quota is maximised.

In practice, both landings taxes and auctions of limited entry licences have also been proposed for Canada's Pacific fisheries [The Commission on Pacific Fisheries Policy (1982)] to deal with the problem of excess fishing capacity. New Zealand, which has ITQ regulations for 32 of its fisheries, is the only country that has systematically attempted to capture rent from its domestic fisheries. Originally, resource rental payments were proposed on the basis of the value of traded quota but opposition from fishers has led to the setting of quota fees using a measure of industry profitability and target rates of return [Clark et al. (1988)]. The rent captured is substantial and amounted to some 10 percent of the value of domestic landings for the 1987-88 fishing season. Other countries have also proposed rent capture for their fisheries. In particular, Australia has suggested auctioning and leasing of access rights, lump sum taxes on fishers, and royalty or landing taxes on fish [Australian Commonwealth Government (1989)]. The issue of rent capture is also of interest in countries such as the USA which is contemplating moving to rights based management in its fisheries. In the case of the US fisheries, the total capitalised value of introduced ITQ's may be as much as several billion dollars [N.Y Times (1991)].

The introduction of rights based management in fisheries has now changed the questions that economists must address. The issue is now no longer of controlling rent dissipation in open access and regulated fisheries but one of capturing rent in rights based fisheries. Despite a wide-body of work on the issues of rent and its capture in resource economics, important questions with respect to rent and its capture in
fisheries still remain unanswered. They include the effect of different taxes on the
distribution of fishers' net returns, the relative flexibility of different methods of rent
capture to adjust to changes in the fishery, their effects on efficiency, ability to collect
rent, cost of collection and risk sharing between fishers and the resource owner. These
questions are addressed in the following chapters.

1.4 Overview

Chapter 2 provides a review of the meaning and significance of economic, differential,
resource or scarcity, quasi, and intra-marginal rents. The purpose is to present the
classical and modern views of rent so as to better understand the nature of rent in
fisheries. In particular, the chapter explains why the capture of resource rent may be
justified and why the collection of intra-marginal rents may not. The former may
be attributed to the scarcity value of the resource while the intra-marginal rents may
be attributable to other factors of production. These intra-marginal rents may be
termed quasi-rents but only in the sense that there are short run rents attributable
to factors of production other than the resource. In the rest of the economy it is not
customary to capture such rents, and the retention of these earnings by fishers may
be necessary to encourage long run innovations in the fishery. In a Schumpeterian view
of the world, such quasi-rents are a necessary incentive for entrepreneurs to undertake
innovation. Their capture by the resource owner may, therefore, reduce the long
run net returns available from the fishery. Another issue addressed in the review of
the notions of rent is the concept of management rent as applied to fisheries. The
difference between the resource and management rent is explained as is the importance
of the notions in rights based fisheries.

Chapter 3 presents the conceptual framework for examining the issue of rent
capture in an ITQ fishery. The approach taken is to develop a theoretical model of a fishery where there are two types of fishers that differ only with respect to their harvesting functions and fixed costs. In particular, it compares a short-run quota equilibrium and a first best situation where the resource owner maximises the expected utility of fishers net of collection costs. The difference between the short-run and a first-best optimum is demonstrated as is the effect of uncertainty upon the quota equilibrium. It is found that increasing the uncertainty in the fishery as defined by the variance of the output price will never increase the expected rent in the fishery and in general will decrease it. Reducing the risk that is faced by a subset of fishers may, however, decrease or increase the total expected rents in the fishery.

Chapter 4 compares the different methods of rent capture using the framework developed in the preceding chapter. It is shown that a quota transfer charge and a lump sum fee are both capable of distorting the Pareto efficient quota equilibrium while capturing an amount no more than the estimated resource rent. The various methods of rent capture are also shown to have differential effects with respect to the rental paid by the two types of fishers. For example, those fishers who earn higher profits per unit of quota harvested will pay proportionately less with a quota rental charge than a profit charge than a fisher with a lower profit per unit of quota. The methods of rent capture are also compared with respect to the cost of collecting the rent by the resource owner. In addition, risk sharing between the resource owner and fishers under the various schemes is examined. Assuming variability in the output price, it is shown that a profit charge, net cash flow charge, and ad valorem royalty cannot decrease and will in general increase the expected rent in the fishery. In contrast, a quota rental charge is found to leave the quota equilibrium unchanged given output price uncertainty and a certain quota price.

Chapter 5 addresses the issue of rent capture in a specific fishery. In particular,
different approaches are used to estimate the rent in the BC sablefish fishery in 1988 two years prior to the introduction of individual quota management. In one approach, using data directly from a costs and earnings survey of 28 of the 46 active fishers in 1988, an estimate of a total sablefish rent of some $6.2 million is obtained. Using the fishers' estimated market value of sablefish fishing licences, an annual resource rent less an allowance for risk costs is obtained. Depending upon the assumed payback period of fishers and using a discount rate set equal to an opportunity cost of capital assumed to be faced by fishers, the annual resource rent is estimated to be between $1.6 and $3.7 million. In another approach, two flexible functional form profit functions are estimated. These profit functions are used to provide estimates of the returns to fishers interviewed in the costs and earnings survey. Using the estimated coefficients from the functions and updating prices for 1990, estimates of the rent in the fishery for 1990 are obtained. Adjusting for the structural change in the fishery due to quota management, an estimate of the total sablefish profits in 1990 of $8.5 and $8.7 million are obtained from the two profit functions.

Chapter 6 uses the predicted sablefish profits for 1990 from the two profit functions to examine the issues of rent capture in the BC sablefish fishery. Comparisons are made of the various methods of rent capture by comparing the rent paid by two different types of vessels found in the fishery. It is found that vessels employing a trap or pot method of harvesting sablefish prefer in a descending order of preference a lump sum charge, *ad valorem* royalty, net cash flow charge, profit charge and a quota rental charge. In contrast, vessels employing another harvesting method have a reverse ordering for the rent capture schemes. The relative preference for the rent capture schemes is shown to be a function of the prices received for sablefish by fishers, the ratio of their net cash flow earnings to their profits, their quota-holdings, and profits per quantity of sablefish harvested. The chapter also addresses the issue
of distortions to the short-run quota equilibrium brought about by rent capture. It is shown that a lump sum charge imposes inefficiencies on the fishery at relatively low levels of rent capture. An attempt is also made to separate the expected resource rent from the intra-marginal rents of fishers in the predicted profits of fishers.

Chapter 7 summarises the contributions of the thesis from both the theoretical and empirical perspective. The chapter concludes with recommendations for further research and suggested extensions to the work.
Chapter 2

The Nature of Rent

... we must inquire into the nature of rent, and the laws by which its rise or fall is regulated.


2.1 Classical View of Rent

The notion of rent, as applied to land, was the subject of great debate among classical economists. It was Adam Smith who observed that "The rent of land not only varies with its fertility, whatever be its produce, but with its situation, whatever be its fertility." [A. Smith (1776), Book I, 164] He also noted that rent, "... is naturally a monopoly price." [Smith (1776), Book I, 162] Rent accrues to land, therefore, because of its limited supply and differences in quality and location.

For expanding upon these notions and addressing ambiguities left by Smith, Ricardo\(^1\) (1817) deserves credit for the classical notion of differential rent which he defined as the infra-marginal return to land blessed with a higher marginal productivity. In the theory, land at the extensive margin receives no rent but each unit of land of successively greater productivity receives rent at a correspondingly higher

\(^1\)Concurrent with Ricardo’s work were publications by West, Torrens and Malthus. Letters from Ricardo to Malthus and others in 1813 and 1814 suggest the claim for the originality of his work may be preeminent.
level. The existence of rent is itself explained by the scarcity of land and the existence of diminishing returns for “... rent invariably proceeds from the employment of an additional quantity of labour with a proportionately less return.” [Ricardo (1817), 37]

Writing some 30 years later, J.S. Mill defended Ricardo from critics who argued from the American experience that the worst land is cultivated before the more productive land. J.S Mill explained that rent reflects a scarcity price and that land differed from labour or capital in that it is “... not susceptible to indefinite increase. Its extent is limited, and the extent of the more productive kinds more limited still.” [J.S. Mill (1848), 176] He also agreed with Ricardo’s notion of differential rent such that “... no land ever pays rent, unless in point of fertility or situation, it belongs to those superior kinds which exist in less quantity than the demand.” [J.S. Mill (1848), 423] He further expanded upon the notion that the rent land could earn in an alternative activity constituted a cost that must be paid if it is used in another. This concept is at the root of the modern notion of a transfer price for a factor of production; the minimum price that must be paid to keep the factor in its present employment. Earnings to the factor above the transfer price constitute rent.

The central issue in the classical notion of rent is, therefore, that rent reflects a payment for scarcity and that the differential rents arise from diminishing returns given a fixed factor of production. In this, Ricardo may be viewed as the first marginalist although he presented his ideas in a proportional framework. Given identical costs per unit of input applied to land and the same output price for the produce from the land, competition would ensure that the value of the marginal product of the variable input will be the same across land types and equal to its cost. At the intensive margin, therefore, the value of the last additional unit of the variable input is the same as at the extensive margin. The return to the fixed factor, land, is the
difference between the total revenue and total cost produced from the different land
types. At the extensive margin, no rent is earned as the total revenue equals the total
cost of production. For land of a higher type, each successive unit of the variable unit
reduced its marginal product until the cost of an additional unit of input equalled
the value of its marginal product. The total cost represents the total number of units
of the variable inputs applied multiplied by its price while the total revenue is the
total product multiplied by the output price. The difference between total revenue
and total costs reflects, therefore, the existence of returns in excess of costs on the
successive units of the variable input and may be called differential rent.

Given the acceptance by classical economists of rent as an unearned residual from
a gift of nature, the notion of capturing this surplus for the benefit of society became a
logical deduction. Although Ricardo appears not to have favoured such rent capture
[Blaug (1986), 84], J.S. Mill (1848) did propose a tax on the capital gains from
increases in the price of land. Henry George (1880) went further but was not alone in
proposing a single tax upon land but which exempted returns from site improvements.
According to George such a tax met his own canons of taxation that a tax affect the
incentives for production as little as possible, be cheaply collected, be certain, provide
the least advantage for tax evasion, and be applied fairly. Although never widely
applied, a variant of the George tax, a site value tax with full or partial exemption
on improvements to land, has been adopted by some local governments in Australia,
USA, and New Zealand.

2.2 Modern View of Rent

The classical view of rent was later shown by the marginalist school to be a residual
surplus applicable to any fixed factor and not just land. In this view, the surplus
accruing to a fixed factor is determined by the gap between the average and marginal product of the variable factor. Despite this viewpoint, Marshall (1920) made a distinction between the surplus accruing to 'gifts of nature' and to labour or capital. In separating the two types of rent Marshall introduced a time dimension with respect to rent and defined the concept of quasi-rent as, "... an unnecessary profit in regard to short periods, because no 'special' or 'prime' costs have to be incurred for the production of a machine that, by hypothesis is already made and waiting for its work. But it is a necessary profit in regard to those other (supplementary) costs which must be incurred in the long run in addition to prime costs." [Marshall (1920), p 424]

Quasi-rents, therefore, apply to factors of production temporarily fixed in supply. With respect to capital, quasi-rent is commonly defined as the difference between total revenue and total variable costs or those earnings over and above that required to keep the firm in business in the short run. For other factors of production it may be defined as those earnings in excess of what is necessary to keep the factor in its present use for a given period of time. In the long run, however, factors must earn quasi-rents equal to their transfer price or they will not stay in the present activity. Similarly, quasi-rents that exceed a factor’s transfer price will be eroded over time as additional units enter into the higher value use.

In a modern review on the issue of economic surplus, Currie et al. (1971) define economic rent in the classical tradition as, "... payment to a factor production over and above the minimum necessary to induce it to do its work."[Currie et al. (1971), 758] They also present an alternative definition of economic rent which they attribute to Pareto stating it represents "... the excess payment to a factor over and above the minimum amount necessary to keep it in its 'present occupation.' " [Currie et

\footnote{Marshall himself never gave such a definition of quasi-rents but this has become the accepted definition.}
The difference between the two notions is that the classical definition addresses whether the factor is supplied in the economy while the latter deals with the issue of whether it is supplied in its present activity. In both definitions, however, economic rent is a surplus that is reflected in the size of net returns that accrue to the factor.

In resource economics, it is conventional to define economic rent as including both differential (Ricardian) and scarcity rent. The scarcity rent, often called the resource rent, is defined as the difference between the output price and the marginal cost of production. As such, resource rent is a function of the "... marginal conditions of the economic calculus" [Conrad and Gillis (1985), 35] The existence of a resource rent implies there are restrictions placed on the supply of the factor such that there are corresponding limitations on the produce obtained. In the case where resources are in abundant supply then the output price will equal the marginal cost of production and the net price or per unit resource rent will be zero. In this case, the economic rent consists only of a differential rent which arises from contemporaneous exploitation of different grades of the resource.

2.3 Resource Rents and Quasi-rents in Fisheries

In the case of fisheries, the setting of a TAC, often determined by biological considerations, is a restriction on the supply of fish over what would be sold in an open access or unregulated environment. Such a restriction in conjunction with durable and enforceable property rights, can give rise to the existence of a resource rent in a fishery such that the net price of fish is positive. In an ITQ fishery where harvesting rights are durable and freely transferable in a competitive market, the price of quota should

\[F.J. \text{ Anderson (1985), 141-142 provides a graphical explanation of the concepts of differential and scarcity rents.}\]
approximate the resource rent attributable to the scarcity value of the fish. This is because the quota price will reflect the difference between the output price of fish and the marginal harvesting cost. Assuming risk neutrality of fishers, all fishers are price takers in the output and factor markets, and that quota is tradeable, equilibrium in the quota market implies that all fishers face the same marginal costs of production. For example, if a fisher faced a higher/lower marginal cost than other resource users then it would pay the individual to sell/buy quota until his or her own valuation of quota equaled the market price.

In addition to a resource rent, there may also exist intra-marginal rents in a fishery. These intra-marginal rents are quasi-rents in that they are essentially a short-run phenomena and are determined by the average total costs of fishers and represent the differential net earnings by resource users in a fishery. The intra-marginal rent in a fishery represents, therefore, the difference in the average profit per unit of fish landed between the marginal fisher and all other fishers. Intra-marginal rents, however, should not to be confused with differential rents that arise from a differential quality of the natural resource. With few exceptions, fishers harvest from essentially the same resource. The existence of intra-marginal returns is explained by differences in human capital or fishing technology applied by fishers.

One explanation for differential earnings among fishers that does not assume the existence of intra-marginal rents is that fishing is a chancy business. For example, in one year one may be fortunate enough to land the entire quota for the season in one set of the fishing gear and hence incur a low cost of production. An individual of similar skill and with the same sized vessel and harvesting process may have the misfortune of spending many days at sea prior to catching the season’s quota. The result is differential net returns among fishers of similar type. Such chanciness in fishing should be reflected in the quota price and any intra-marginal earnings due to
good luck may be necessary to compensate for losses in other periods. This description of differential earnings among fishers explains away the existence of intra-marginal rents. Such ‘rents’ are merely the product of the capriciousness of nature and as such are not attributable to any factor of production in the short or long run.

An alternative explanation for differential earnings among fishers that does assume the existence of intra-marginal rents is that it arises from fishing and/or management skill of fishing captains. Differences in skills among fishers, therefore, explains differences in average total harvesting costs. In this explanation, intra-marginal rents are like quasi-rents in that they are temporary in nature. \(^4\) Quality differences among fishing captains may be further accentuated by the type of remuneration paid to crew in the fishing industry. Often crew are paid a percentage of the landed value of the catch that is usually fixed by convention for the fishing fleet. Consequently, better fishing captains may be in a preferred position to have first choice on the crew hired and select for better workers. Thus according to Copes “… the differential in overall efficiency between vessels is maintained with resulting large differences between ‘high-liners’ and vessels at the bottom of the efficiency scale.” [Copes (1972), 151]

Another explanation for the existence of intra-marginal rents is the use of different fishing technology among vessels. In this view, captains and crew are essentially the same and cost differentials are explained by the use of different vessels and harvesting methods. As older or less productive capital and gear is replaced such quasi-rents would be eroded over time.

It is conventional in other resource sectors that owners of the minerals extracted by mining operations or of the trees harvested by logging operations should be paid some share of the resource rent. In this case, the resource rent paid to the resource owner

\(^4\)Marshall noted that “… earnings even of rare abilities are, as we have seen, to be regarded rather as a quasi-rent than as a rent proper.” [Marshall (1920), 623]
by the resource user is a payment for the right to extract or harvest the resource. In the case of a fishery, individual owners of ITQ's have an exclusive harvesting right to the resource. Where the resource owner chooses not to capture the resource rent then this rent will accrue to the original quota-holders or those individuals fortunate enough to be allocated quota at the beginning of ITQ management. If one accepts the notion that the owners of a resource should be the principal beneficiaries from others using the resource then the capture of resource rent is an appropriate activity.

The capture of intra-marginal rents of fishers by a resource owner, however, cannot be justified on the same grounds as the collection of resource rent. If one accepts that intra-marginal rents are a function of fishing skill and/or the use of superior harvesting technology, then the rents are attributable to factors of production other than the resource. In the case of the fishing skill of the captain, the intra-marginal rent is a reflection of embodied human capital of the individual. In the example of a superior harvesting gear, the intra-marginal rents are attributable to the specific capital employed. Only when differential returns among fishers is explained by good or ill chance can such earnings not be attributed to a factor of production. Irrespective of the explanation, all such earnings are temporary in nature.

The collection of intra-marginal rents may be tempting for a resource owner but it does impose costs that would not arise with the collection of the resource rent. It may be that windfall gains through good chance may be necessary to compensate fishers for being employed in a risky profession. The collection of such earnings may, therefore, lead to the exit of fishers who require the expectation of such returns to harvest the resource. Equally, if one accepts that intra-marginal rents are above normal returns that accrue to high-liners then the capture of such rents may drive better fishers out of the fishery. More importantly, the existence of intra-marginal rents may be the incentive for innovation by fishers. According to Schumpeter (1934,
In this sense, "... entrepreneurial profits are the prizes offered by capitalistic society to the successful innovator." [Schumpeter (1950), 102] The capture of intra-marginal rents from fishers may, therefore, reduce the incentive for innovation. As a result, innovations that would have led to cost reductions and increases in the total net return in the fishery may never arise in an environment where such rents are appropriated.

In addition to resource rents and intra-marginal rents, there may also exist a quasi-rent for the marginal fisher. This quasi-rent will arise when ITQ's are allocated *gratis* among fishers and there is a time lag before other fishers are able to enter the fishery. In the time period before fishers are able to acquire the necessary gear and/or vessels to operate in the fishery, the quota price will be determined by the current quota-holders. In this period, if the marginal cost of the marginal fisher exceeds its average cost at the short-run quota equilibrium, the marginal fisher will be earning an annual profit in excess of the lease value of its quota-holdings. This difference may be termed a 'marginal quasi-rent'. Over time, this quasi-rent would attract new entrants into the fishery increasing the quota price until the marginal fisher earned only a resource rent. Unlike an intra-marginal rent which is also short run in nature, a marginal quasi-rent accrues to fishers whose only virtue were to be original participants in the fishery. It does not arise from differential skill among fishers or from the use of different fishing technology. As such, capture of the marginal quasi-rent by the resource owner should not affect the incentives for innovation by fishers. An illustration of the different types of short-run rent in an ITQ fishery is presented in Figure 2.1. This represents a fishery where all fishers are earning a marginal quasi-rent. Where fishers are operating at a point below their minimum average cost of production and given increasing marginal costs, fisher profits will be less than the resource rent. In this scenario there will only exist resource and intra-marginal rents in the fishery.
Another concept applied specifically in rights based fisheries is that of management rent [Anderson (1989)]. In comparing a fishery in an open-access environment with one subsequently managed with ITQ's, Anderson notes that the management rent is simply the total value of individual quotas. The management rent, in this case, is identical to the resource rent. Recognising that most developed fisheries today are not in an open-access situation and rights based management is often imposed on fisheries regulated with prior restrictions on fishing effort, an alternative definition of management rent may be offered. Management rent may be defined as the change in the resource rent brought about by a change in fisheries management less the difference in management costs between the new and old policies. In this definition, it is possible for management rent to be negative if increases in the resource rent are more than offset by increased costs of managing or regulating the fishery under the new policy. The maximum value of the management rent would, therefore, be a change in management from an open-access, zero resource rent situation, to the rent maximising harvest level taking into account regulatory costs. The importance of the notion of management rent is that it recognises that the costs of regulation are a true cost to society. The net benefit to society of rights based management is, therefore, the management rather than the resource rent in the fishery.
Figure 2.1: Short-Run rent in an ITQ Fishery

ABEF: resource rent fisher 1
ACDF: resource rent fisher 2
FEHG: marginal quasi-rent fisher 1
FDIG: marginal quasi-rent fisher 2
GIJK: intra-marginal rent

Γ = quota price
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It is not necessary to confiscate land; it is only necessary to confiscate rent.

Henry George (1839-1897), Progress and Poverty, Book VIII, Ch II, p. 403.

3.1 Introduction

The issue of capturing rent in an ITQ fishery requires a number of assumptions to be able to examine the problem in a tractable framework. In developing a theoretical model of an ITQ fishery, it is assumed that the initial biomass is set at a level that would maximise the sum of the expected utility of fishers in a first best situation and that the harvest equals the growth in the biomass each period. Such assumptions preclude addressing the issue of an optimal approach path to an optimal biomass level. These questions, however, are well addressed in the literature.\(^1\)

The theoretical environment assumed for evaluating alternative methods of rent capture is that of a fishery where management is vested in a resource owner and all prices are given. The question of uncertainty and risk is addressed by assuming that the output price is not known at the beginning of each period but there is a known and spherically symmetric probability distribution for the variable. In the first instance, the first best problem is examined where for a given amount of rent to be captured

\(^1\)See for example Clark and Munro (1975) and Clark, Clarke, and Munro (1979).
the resource owner seeks to maximise the sum of the expected utility of fishers net of collection costs. This outcome is then compared to the short-run quota equilibrium that arises from ITQ management under the assumptions that quota was originally allocated gratis to fishers, trades at a positive price, and is denominated in quantity of fish that may be harvested per unit of time. In both cases, fishers are assumed to utilise one of two distinct fishing technologies.

3.2 The Model

Following Andersen (1982), an optimal fishery under price uncertainty may be defined by maximisation of the expected rent above risk costs of the fishers. This implies that the resource owner is risk neutral and that risk is only considered with respect to individual fishers. The problem posed in the first-best situation is to maximise the sum of the expected utility of profits of fishers for a given amount of rent to be captured net of collection costs. In the case where the risk costs of fishers and/or the collection costs are dependent upon the output of fishers this is not the same as maximising the expected rent in the fishery. The objective function is equivalent to maximising the general welfare of fishers defined as the simple sum of their individual von Neumann-Morgenstern utilities.\(^2\) Provided that the random variable has a spherical and symmetric probability distribution [Chamberlain (1983)], such a framework is consistent with maximising the sum of the mean-variance expected utility functions of fishers.

In solving the first-best problem, it is assumed that the quantity of fish harvested by each individual of each type, the number of fishers of each type, the biomass, and the rent collected from each fisher is determined prior to revelation of the value of

\(^2\)This specification is analogous to a classical utilitarian welfare function. The axioms necessary to generate the von Neumann-Morgenstern utility functions are presented in Hey (1978), chapter 4.
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the random variable. It is assumed that the social rate of discount is zero and that there exists several non mutually exclusive methods of rent capture available. The notation used to describe the first-best problem is defined as follows:

$k$ denotes individual fisher employing the F1 technology.

$j$ denotes individual fisher employing the F2 technology.

$l$ denotes a method of rent capture employed by the resource owner.

$L$ is the total number of rent capture methods available to the resource owner.

$N$ is the optimum number of F1 type fishers.

$M$ is the optimum number of F2 type fishers.

$P$ is the price of fish.

$C$ is the cost per unit of fishing effort.

$f_{c1}$ is the fixed cost of a F1 type fisher.

$f_{c2}$ is the fixed cost of a F2 type fisher.

$\pi_{1k}$ is the profit of individual $k$, F1 type fisher.

$q_{1k}$ is the total harvest of an individual $k$, F1 type fisher.

$e_{1k}$ is the total fishing effort of an individual $k$, F1 type fisher.

$\xi_1$ is the catchability coefficient for F1 type fisher.

$\pi_{2j}$ is the profit of individual $j$, F2 type fisher.

$q_{2j}$ is the total harvest of individual $j$, F2 type fisher.

$e_{2j}$ is the total fishing effort of an individual $j$, F2 type fisher.

$\xi_2$ is the catchability coefficient for F2 type fisher.

$b$ is the total fish biomass.

$\bar{b}$ is the maximum attainable biomass.

$B$ is a constant.

$o_{kl}$ is the rent collected from individual $k$, F1 fisher using capture method $l$. 
\( o_{jl} \) is the rent collected from individual \( j \), F2 fisher using capture method \( l \).

\( v_{1l}(.) \) is the variable collection costs with rent capture method \( l \) on F1 fishers.

\( v_{2l}(.) \) is the variable collection costs with rent capture method \( l \) on F2 fishers.

\( K \) is the fixed collection costs associated with rent capture method \( l \).

\( W \) is the total amount of rent captured from the fishery.

\( \mathcal{E} \) is an expectations operator.

**First Best Problem**

Maximise with respect to \([N, M, b, q_{1k}, q_{2j}, o_{kl}, o_{jl}]\)

\[
\mathcal{E}\{ \sum_{k=1}^{N} U(\pi_{1k}) + \sum_{j=1}^{M} U(\pi_{2j}) \}
\]

subject to:

\[
Pq_{1k} - C \frac{q_{1k}^2}{\xi_1 b^2} - f_{c1} - \sum_{l=1}^{L} o_{kl} = \pi_{1k} \geq 0 \quad (3.1)
\]

\[
Pq_{2j} - C \frac{q_{2j}^2}{\xi_2 b^2} - f_{c2} - \sum_{l=1}^{L} o_{jl} = \pi_{2j} \geq 0 \quad (3.2)
\]

\[
\sum_{k=1}^{N} q_{1k} + \sum_{j=1}^{M} q_{2j} = b(b - \bar{b}) \quad (3.3)
\]

\[
\sum_{k=1}^{N} o_{kl} + \sum_{j=1}^{M} o_{jl} - v_{1l}(.) - v_{2l}(.) - K = W \quad (3.4)
\]

where: if \( q_{1k}, N, \) or \( o_{kl} = 0 \ \forall \ k \) then \( v_{1l}(q_{1k}, N, o_{kl}) = 0 \) and if \( q_{2j}, M, \) or \( o_{jl} = 0 \ \forall \ j \) then \( v_{2l}(q_{2j}, M, o_{jl}) = 0 \). (3.1) is the profit of an F1 type fisher after rent capture which must be non negative, (3.2) is the profit of an F2 type fisher after rent capture which must be non negative, (3.3) is an equilibrium condition that ensures that the total harvest equals the growth in the biomass, (3.4) is the amount of rent collected from the fishery net of collection costs.

Provided that a solution exists to the first best problem for a given \( W \) then the solution will depend on the values of the exogenous variables \( \mathcal{E}\{P\}, C, B, \bar{b}, f_{c1}, f_{c2}, \)
the variable and fixed costs of rent capture $v_{1i}(\cdot)$, $v_{2i}(\cdot)$ and $K_i$, the variance of the output price $\sigma_p^2$, and the risk aversion parameters of F1 and F2 fishers. In this model, the harvest functions are increasing and concave with respect to effort where effort is defined as some composite variable of fisher’s inputs.\(^3\) This differs from the assumption often applied in the literature of a harvesting function that is increasing but linear with respect to effort. Concavity of the harvesting functions may arise from gear saturation that reduces the catchability of fishing gear and congestion among fishing vessels on fishing grounds [Clark (1990), 222-225]. The harvest is increasing with respect to the biomass of the fishery indicating, *ceteris paribus*, that a greater stock of fish will yield a higher catch per unit of effort. The growth function of the fishery assumes a parabolic relationship between surplus production or yield and the size of the stock. This is derived from the assumption that a fish stock produces its greatest harvestable surplus when it is at an intermediate and not at a maximum level of abundance. This may be due to several causes including the fact that recruitment of new cohorts into a fishery is often hampered by higher densities and that greater pressure on food stocks often means a larger fraction of calories is used merely to maintain life rather than for growth [Ricker (1987), 309-316].

Under a mean-variance specification of expected utility [Just et al. (1982), Tobin (1969), and Diamond and Rothschild (1988)] with no uncertainty defined as $\sigma_p^2 = 0$ or rent capture defined as $o_{kl} = o_{jl} = 0 \ \forall \ k, j$, the solution to the first best problem given by $q_{1k}^*, q_{2j}^*, N^*, M^*$, and $b^*$ maximises the expected rents in the fishery. Under uncertainty and no rent capture, the solution to the first-best problem will maximise the expected rent in the fishery less the risk costs of fishers. Given no uncertainty but with rent capture, the first-best problem will maximise the expected rents in the fishery less collection costs. In this case, the only consideration for choosing a

\[^{3}\]The harvesting function of a fisher i may be written as $q_i = \xi_i e^{\frac{k}{b}}$. 
method of rent capture is the cost of rent collection. In the case of both uncertainty and rent capture, the first-best problem maximises the expected rent less the risk costs of fishers and less the collection costs of rent capture. In this case, the choice of the rent capture method is determined by both the cost of rent collection and its effect upon the risk costs of fishers. For example, a method of rent capture may have lower collection costs for any values of \( N, M, q_{1k}, \) and \( q_{2j} \) but may be a less desirable method of rent capture than another if it imposes higher risk costs on fishers.

Because actual fisheries are almost never at a first-best optimum, it is useful to compare the short-run equilibrium in an ITQ fishery to the solution in the first-best problem. In this respect, the analysis diverges from the traditional fisheries literature which has primarily been concerned with the optimum allocation of fishing effort in a first-best or long-run situation. The short-run is defined as the time necessary to allow for transactions of quota among fishers already in the fishery and the long-run as the time necessary to allow for entry and exit of all vessels. In comparing the short-run equilibrium to the first-best solution, the number of vessels fishing (including both \( F_1 \) and \( F_2 \) fishers) and the TAC in the ITQ fishery is set equal to the total number of fishers and harvest level in the first-best problem given no uncertainty or rent capture. It is further assumed that both types of fishers are operating in the fishery upon introduction of ITQ management and that the TAC is initially allocated equally among all fishers at no charge.

Operating in the fishery are two types of fishers; those who employ a type one technology (\( F_1 \)) and those who employ a type two technology (\( F_2 \)). The \( F_1 \) type fishers are assumed to have a higher catchability coefficient but incur higher fixed costs than the \( F_2 \) fishers. Such an assumption reflects the existence in a number of fisheries of vessels with more modern search and harvesting technology operating simultaneously with vessels employing more traditional harvesting methods.
In trading quota, it is assumed that each fisher buys/sells or leases the quota they desire immediately after receiving their initial allocation of quota until a market equilibrium is achieved. Each fisher is assumed to maximise the expected utility of economic profits each time period given their level of fixed costs and fishing technology. It is assumed, therefore, that fishers make their harvesting and quota trading decisions with sole regard to short-run economic profits and do not consider long-run investments. Such an assumption is reasonable in that fishers' capital and technology are fixed in the short-run, quota is freely tradable, and that the TAC is determined exogenously. As a result, the current decisions of fishers will have no effect, direct or indirect, on their profits in future periods. Fishers simply maximise their expected utility per time period by choice of their fishing effort and the quantity traded.

The economic profit of fishers is defined as their total revenue less fixed and variable harvesting costs and less the opportunity cost of owning quota at each time period. A fisher's opportunity cost is defined as the annuity that would be earned if quota were sold/leased and the funds were invested elsewhere in the economy at a competitive rate of interest. It is best understood in the context that quota is an asset and imposes a cost on its owner whether it is bought, leased or obtained gratis from the regulator. The uncertainty faced by fishers is that they must undertake harvesting and quota-trading decisions prior to knowing the output price. The fishers' belief about the output price is summarised by a probability distribution that is defined by its mean and variance. Fishers are further assumed to be price takers in the output, input, and quota markets. Under these assumptions, the general maximisation problem faced by fishers at beginning of period \( t = 1 \) when quota is first traded is presented below.

The notation used to describe the problem is as defined previously and includes:
\( \Phi_{kt} \) is the economic profit of fisher \( k \) using \( F1 \) technology in period \( t \).

\( \Phi_{jt} \) is the economic profit of fisher \( j \) using \( F2 \) technology in period \( t \).

\( r \) is the competitive rate of interest.

\( q_{1kt} \) is the quantity harvested by fisher \( k \) using \( F1 \) technology in period \( t \).

\( q_{2jt} \) is the quantity harvested by fisher \( j \) using \( F2 \) technology in period \( t \).

\( e_{1kt} \) is fishing effort in period \( t \) by fisher \( k \) using \( F1 \) technology.

\( e_{2jt} \) is fishing effort in period \( t \) by fisher \( j \) using \( F2 \) technology.

\( \Gamma_t \) is the market price of quota in period \( t \).

\( A_{k,j} \) is the initial quota allocation to fisher \( k, j \).

\( w_{kt,jt} \) is the quantity traded by fisher \( k,j \) in period \( t \).

\( \delta \) is a discount factor equal to \((1 + r)^{-1}\).

**Maximisation Problem of Fishers**

Fisher \( k \) employing a \( F1 \) type technology maximises with respect to \([e_{1kt}, w_{kt}]\):

\[
\mathbb{E}\left\{ \sum_{t=1}^{T} \delta^t U(\Phi_{kt}) \right\}
\]

subject to:

\[
q_{1kt}(e_{1kt}; b) \leq A_k + w_{kt} \quad (3.5)
\]

where for fisher \( k \) employing fishing technology \( F1 \):

\[
\Phi_{kt} = P_t q_{1kt} - C e_{1kt} - fc_1 - \Gamma_t r (A_k + w_{kt})
\]

\( w_{kt} > 0 \) if quota is bought/leased and \( w_{kt} < 0 \) if sold/leased out.

Fisher \( j \) employing a \( F2 \) type technology maximises with respect to \([e_{2jt}, w_{jt}]\):
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\[
E\{\sum_{t=1}^{T} \delta^t U(\Phi_{jt})\}
\]

subject to:

\[
g_{2jt}(e_{2jt}; b) \leq A_j + w_{jt} \tag{3.6}
\]

where for fisher \( j \) employing fishing technology \( F2 \):

\[
\Phi_{jt} = P_t q_{2jt} - C e_{2jt} - f c_2 - \Gamma r (A_j + w_{jt})
\]

\( w_{jt} > 0 \) if quota is bought/leased and \( w_{jt} < 0 \) if sold/leased out.

Given the separable nature of the problem faced by fishers in the short-run, one may examine the independent maximisation of \( \Phi_{kt} \) or \( \Phi_{jt} \) for \( t = 1, \ldots, T \). In solving for the individual fishers’ quota demands, we note that if fishers face binding quota constraints such that quota is valuable then the harvest of fishers will not be less than the quota owned and/or leased provided that quota-holdings are known with certainty. Consequently, (3.5) and (3.6) hold with strict equality such that \( A_{k,j} \) and \( w_{kt,jt} \) can be substituted by \( g_{1kt,2jt} \) in the respective maximisation problem. Using the fishers’ harvesting functions one may also solve for the level of effort \( (e_{1kt}, e_{2jt}) \) as a function of the quantity harvested and the biomass.

In addressing the issue of uncertainty, fishers are assumed to exhibit risk averse preferences and face a fluctuating output price whose mean and variance is known. The notion of risk averse preferences for fishers is adopted by Andersen (1982) who assumes that fishers are risk averse and maximise the expected utility of profit. Clark (1985), however, takes a different view with respect to the short-term decision-making of fishers and suggest fishers have “... a gambler’s taste for the daily ups and downs of their vocation” [Clark (1985), 230]. A review of the issues of uncertainty in fisheries
in general is presented in Andersen and Sutinen (1984) and uncertainty and dynamics in Clark et al. (1985). In a particular study of the Eastern Pacific yellowfin tuna fishery, Lewis (1981) has examined the question of how optimal policies change under stochastic conditions. He shows that the problem of optimal management under uncertainty can be treated as a certainty-equivalent situation. Charles (1983) examining the issue of investment and uncertainty has shown that optimal fleet capacity with uncertainty will depend upon both the growth rate of the fish stock and the cost of capital.

The uncertainty that fishers may face includes fluctuations in the TAC, the output price, price of inputs, and the quota price. For ease of analysis, the effects of uncertainty on the behaviour of fishers is examined only with respect to fluctuations in the output price. The uncertainty faced by fishers is that they must choose the quantity of fish to harvest and quota to be traded at the beginning of each period prior to knowing the output price. Given that the random variable is normally distributed the expected utility of fishers can be represented by a mean-variance specification.\(^4\)

Under the assumption of separability across time, the specific maximisation of problem of fisher \(k\) using technology \(F_1\) at time period \(t\) may be defined as follows:

\[
E\{U(\Phi_{kt})\} = E(\Phi_{kt}) - \beta_1 E(\Phi_{kt} - E(\Phi_{kt}))^2
\]

\[
= \{\overline{P} q_{kt} - C_e(q_{kt}; b) - f c_1 - \Gamma_1 r q_{kt} - \beta_1 E(\Phi_{kt} - E(\Phi_{kt}))^2\} \quad (3.7)
\]

where \(\overline{P}\) is the expected price of fish, \(U\) is the utility function which is bounded from above, \(\Phi_{kt}\) is the economic profit of fisher \(k\), \(\beta_1\) is the risk aversion parameter for \(F_1\) type fishers, \(E(\Phi_{kt} - E(\Phi_{kt}))^2\) is the variance of economic profit, and \(\beta_1 E(\Phi_{kt} - E(\Phi_{kt}))^2\)

\(^4\)For a review of the appropriateness of the mean-variance specification see Diamond and Rothschild (1988), p 141. and Just et al. (1982), chapter 11.
is the risk premium associated with random fluctuations in the output price.

The variance of the economic profit of fisher $k$ may be determined by (3.8)

$$E\{\Phi_{kt} - E(\Phi_{kt})\}^2 = E\{Pq_{kt} - C\frac{q_{kt}^2}{\xi_1^2 b^2} - fc_1 - \Gamma_t r q_{kt} - (Pq_{kt} - C\frac{q_{kt}^2}{\xi_1^2 b^2} - fc_1 - \Gamma_t r q_{kt})\}^2$$

$$= E\{(P - \bar{P})q_{kt}\}^2$$

$$= q_{kt}^2 E(P - \bar{P})^2$$

$$= q_{kt}^2 \sigma_P^2$$ (3.8)

Similarly for a fisher $j$ using an F2 technology the variance of economic profit is,

$$E(\Phi_{jt} - E(\Phi_{jt}))^2 = q_{2jt}^2 \sigma_P^2$$ (3.9)

Substituting (3.8) into (3.7), the maximisation problem for an F1 type fisher facing random fluctuations in the output price in period $t$ becomes,

$$E[U(\Phi_{kt})] = [\bar{P}q_{kt} - C\frac{q_{kt}^2}{\xi_1^2 b^2} - fc_1 - \Gamma_t r q_{kt} - \beta q_{kt}^2 \sigma_P^2]$$ (3.10)

Maximising with respect to $q_{kt}$ we obtain the following first order condition:

$$\frac{\partial E[U(\Phi_{kt})]}{\partial q_{kt}} = [\bar{P} - C\frac{q_{kt}^2}{\xi_1^2 b^2} - \Gamma_t r - 2\beta q_{kt} \sigma_P^2] = 0$$ (3.11)

Solving (3.11) in terms of $q_{kt}$,

$$q_{kt} = \frac{\xi_1^2 b^2 [\bar{P} - \Gamma_t r]}{[2C + 2\xi_1^2 b^2 \beta \sigma_P^2]}$$ (3.12)

The maximisation problem for an F2 fisher simplifies as follows,

$$E[U(\Phi_{jt})] = [\bar{P}q_{jt} - C\frac{q_{jt}^2}{\xi_2^2 b^2} - fc_2 - \Gamma_t r q_{jt} - \beta q_{jt}^2 \sigma_P^2]$$ (3.13)

Maximising with respect to $q_{jt}$ we obtain the following first order condition:

$$\frac{\partial E[U(\Phi_{jt})]}{\partial q_{jt}} = [\bar{P} - C\frac{q_{jt}^2}{\xi_2^2 b^2} - \Gamma_t r - 2\beta q_{jt} \sigma_P^2] = 0$$ (3.14)
Solving (3.14) in terms of \( q_{2jt} \),

\[
q_{2jt}^* = \frac{\xi_2^2 b^2 [\bar{P} - \Gamma_t]}{[2C + 2\xi_2^2 b^2 \beta_2 \sigma_p^2]} \tag{3.15}
\]

The short-run market equilibrium for quota can be solved by multiplying the individual quota demands of the two types of fishers in (3.12) and (3.15), respectively, by the number of F1 and F2 fishers and then setting the product equal to the TAC. The market price of quota can then be determined from the equilibrium condition which if substituted into the respective quota demands can solve for the post-trade quota distribution. This equilibrium represents the quota distribution that would arise given the initial conditions in the fishery. In general, this short-run equilibrium will differ from the long-run optimum since it does not account for the possibility of entry of additional vessels into the fishery.

Defining \( X \) and \( Y \) respectively as the number of F1 and F2 type fishers initially allocated quota and the TAC as the total quota allocation, we obtain the following short-run equilibrium condition:

\[
\text{TAC} = \frac{X \xi_1^2 b^2 [\bar{P} - \Gamma_t]}{[2C + 2\xi_1^2 b^2 \beta_1 \sigma_p^2]} + \frac{Y \xi_2^2 b^2 [\bar{P} - \Gamma_t]}{[2C + 2\xi_2^2 b^2 \beta_2 \sigma_p^2]} \tag{3.16}
\]

Defining,

\[
a_1 = 2C + 2\xi_1^2 b^2 \beta_1 \sigma_p^2
\]

and

\[
a_2 = 2C + 2\xi_2^2 b^2 \beta_2 \sigma_p^2
\]

one may solve (3.16) in terms of the market price of quota (\( \Gamma_t \)) and obtain,

\[
\Gamma_t = \frac{\bar{P}}{r} - \frac{a_1 a_2 \text{TAC}}{[X \xi_1^2 a_2 + Y \xi_2^2 a_1] b^2 r} \tag{3.17}
\]
Differentiating (3.17), the short-run quota price is found to be increasing with respect to the price of fish, the number of fishers, the catchability coefficients, and the biomass and decreasing with respect to the cost per unit of effort, the interest rate, the total quota allocation, the risk aversion parameter of fishers, and the variance of the output price.

The result may be compared to the situation where fishers are risk neutral such that their risk aversion parameters are zero but face the same fluctuations in the output price. The maximand of the F1 fisher in this case simplifies as follows,

\[ E(\Phi_{kt}) = \left[ \bar{P}q_{1kt} - C \frac{q_{1kt}^2}{\xi_1^2 b^2} - fc_1 - \Gamma_t r q_{1kt} \right] \] (3.18)

such that,

\[ q_{1kt}^* = \frac{\xi_1^2 b^2 [\bar{P} - \Gamma_t r]}{2C} \] (3.19)

In the case where fishers are risk averse but face no fluctuations in the output price, the maximand of an F1 fisher also simplifies to (3.18). Consequently, the demand for quota solves as per (3.19). Similarly for an F2 fisher in the case of no uncertainty and risk neutrality

\[ q_{2jt}^* = \frac{\xi_2^2 b^2 [\bar{P} - \Gamma_t r]}{2C} \] (3.20)

In both the risk neutrality and no uncertainty case, the quota price solves to the following,

\[ \Gamma_t = \frac{\bar{P}}{r} - \frac{2C[TAC]}{[X\xi_1^2 + Y\xi_2^2]b^2r} \] (3.21)

Addressing the issue of uncertainty, one may examine the short-run quota equilibrium given \( \sigma_p^2 > 0 \) and \( \beta_1 \) and \( \beta_2 \) are non-zero. In the uncertainty case with risk

\[ \text{see Appendix A for the partial derivatives of the quota price.} \]
aversion, the first order condition for fishers is given by either (3.11) or (3.14). In both equations, the difference between the output price and the marginal cost of production does not equal the quota price. It can be seen, therefore, that the per unit expected resource rent defined by the difference between the expected output price and marginal harvesting cost will exceed the per unit quota price. The difference being accounted for by the amount by which fishers discount the expected output price due to uncertainty. Rearranging the first order condition of a fisher \( k \) using an F1 technology the annual quota price may be written as per (3.22).

\[
\Gamma_{it} = \bar{P} - C_{fit}^q - \frac{2q_{1kt}}{\xi_{it}^2} - 2\beta_k q_{1kt} \sigma_P^2
\]  

(3.22)

The difference between the quota price and per unit expected resource rent is, therefore, given by the last term in the RHS of (3.22). This term may be defined as the marginal risk premium of fisher \( k \). The higher the risk aversion parameter \( \beta_k \) or the higher the uncertainty associated with the output price \( \sigma_P^2 \) then the higher the marginal risk premium and the greater the difference between the per unit expected resource rent and quota price.

Comparing the case where the expected price with uncertainty and risk aversion equals the price with certainty, (3.22) suggests that in general the short-run quota equilibrium will differ between the uncertainty and certainty case where fishers are risk averse. Only in the special case where changes in uncertainty change the quota demands of fishers in the same proportion will increases/decreases in \( \sigma_P^2 \) leave the short-run quota equilibrium unchanged. For F1 and F2 fishers at the quota equilibrium it requires that,

\[
\frac{\partial q_{1kt}}{\partial \sigma_P^2} = \frac{\partial q_{2kt}}{\partial \sigma_P^2} = 0
\]  

(3.23)

This result is perfectly general for any ITQ fishery with a given TAC and a positive quota price. For a change in the level of uncertainty to leave the quota equilibrium
unchanged it must be the case that the quota demands of all fishers must remain unchanged. In the specific fishery example, (3.23) is not implied by equality of the risk aversion parameters and is a function of both the fishers’ harvesting functions and their levels of risk aversion. If and only if \( \beta_1 \xi_1^2 = \beta_2 \xi_2^2 \) will it be true that changing the level of uncertainty will leave the quota equilibrium unchanged. This condition ensures that the ratio of the quota demands of F1 to F2 fishers is equal to the ratio of the catchability coefficients squared of F1 to F2 fishers, i.e., \( \frac{q_{i1}}{q_{i2}} = \frac{\xi_1^2}{\xi_2^2} \). Under this condition, the quota demands are independent of the variance of the output price such that the quota equilibrium is the same with and without uncertainty. When this condition does not hold, the ratio of the quota demands will vary with \( \sigma_p^2 \) such that changing the level of uncertainty will change the short-run quota equilibrium.

Consider the following result.

**Proposition 3.1** For a given TAC, if \( \beta_1 \xi_1^2 = \beta_2 \xi_2^2 \) then \( \frac{\partial q_{i1t}}{\partial \sigma_p^2} = \frac{\partial q_{i2t}}{\partial \sigma_p^2} = 0 \).

**PROOF.** Differentiating (3.12) by \( \sigma_p^2 \) and noting that \( a1 = 2C + 2\xi_1^2 b^2 \beta_1 \sigma_p^2 \) and \( a2 = 2C + 2\xi_2^2 b^2 \beta_2 \sigma_p^2 \).

\[
\frac{\partial q_{i1t}}{\partial \sigma_p^2} = \frac{(\frac{\partial q_{i1t}}{\partial \sigma_p^2}) r \xi_1^2 b^2 a1 - 2\xi_1^4 b^4 \beta_1 (P - \Gamma_t r)}{(a1)^2} \quad (3.24)
\]

For a given TAC, dividing the numerator and denominator of the quota price given by expression (3.17) by \( (a1a2) \) and differentiating with respect to \( \sigma_p^2 \) we obtain,

\[
\frac{\partial \Gamma_t}{\partial \sigma_p^2} = -\frac{\text{TAC}\left(\frac{2\xi_1^4 b^4 \beta_1}{a1^2} + \frac{2\xi_1^4 b^4 \beta_2}{a2^2}\right)}{\left(\frac{X\xi_1^2 b^2}{a1} + \frac{Y\xi_2^2 b^2}{a2}\right)^2} \quad (3.25)
\]

Substituting (3.25) into (3.24), the numerator of the expression becomes

\[
\text{TAC}\left(\frac{2\xi_1^4 b^4 \beta_1}{a1^2} + \frac{2\xi_1^4 b^4 \beta_2}{a2^2}\right) - \frac{\text{TAC}(2\xi_1^4 b^4 \beta_1)}{\left(\frac{X\xi_1^2 b^2}{a1} + \frac{Y\xi_2^2 b^2}{a2}\right)^2} \quad (3.26)
\]
mulitplying the numerator and denominator of the RHS term of (3.26) by \((\frac{x_{\xi_1}^2 b^2}{a_1} + \frac{y_{\xi_1}^2 b^2}{a_2})\) the expression simplifies to

\[
TAC\left( \frac{2\xi_1 b^6}{a_1} + \frac{2\xi_2 Y_{\beta_1} b^6}{a_2} \right) \left( \frac{x_{\xi_1}^2 b^2}{a_1} + \frac{y_{\xi_1}^2 b^2}{a_2} \right)^2 - TAC\left( \frac{2\xi_1 b^6}{a_1} + \frac{2\xi_2 Y_{\beta_1} b^6}{a_2} \right) \left( \frac{x_{\xi_1}^2 b^2}{a_1} + \frac{y_{\xi_1}^2 b^2}{a_2} \right)^2
\]

(3.27)

If \(\beta_1 \xi_1^2 = \beta_2 \xi_2^2\) it follows immediately that \(a_1 = a_2 = a\). Simplifying (3.27) accordingly,

\[
TAC\left( \frac{2\xi_1 b^6}{a} + \frac{2\xi_2 Y_{\beta_1} b^6}{a} \right) \left( \frac{x_{\xi_1}^2 b^2}{a} + \frac{y_{\xi_1}^2 b^2}{a} \right)^2 - TAC\left( \frac{2\xi_1 b^6}{a} + \frac{2\xi_2 Y_{\beta_1} b^6}{a} \right) \left( \frac{x_{\xi_1}^2 b^2}{a} + \frac{y_{\xi_1}^2 b^2}{a} \right)^2
\]

(3.28)

which solves to the following

\[
TAC\left( \frac{(\beta_1 \xi_1^2 - \beta_2 \xi_2^2) 2\xi_1 \xi_2 Y_{\beta_1} b^6}{a} \right) \left( \frac{x_{\xi_1}^2 b^2}{a} + \frac{y_{\xi_1}^2 b^2}{a} \right)^2
\]

(3.29)

If \(\beta_1 \xi_1^2 = \beta_2 \xi_2^2\) it follows immediately that

\[
\frac{\partial q_{lkt}^*}{\partial \sigma^2_p} = 0
\]

(3.30)

Performing similar calculations for \(q_{2jt}^*\) by differentiating (3.15) with respect to \(\sigma^2_p\)

\[
\frac{\partial q_{2jt}^*}{\partial \sigma^2_p} = \frac{(-\frac{\partial T_t}{\partial \sigma^2_p}) r\xi_2^2 b^2 a2 - 2\xi_1^4 b^4 \beta_2 (P - \Gamma_t r)}{(a2)^2}
\]

(3.31)

Substituting (3.25) into (3.31), the numerator of the expression becomes

\[
TAC\left( \frac{2\xi_1^4 X_{\beta_1} b^6 a^2}{a_1^2} + \frac{2\xi_2^4 Y_{\beta_2} b^6}{a_2^2} \right) \left( \frac{x_{\xi_1}^2 b^2}{a_1} + \frac{y_{\xi_1}^2 b^2}{a_2} \right)^2 - TAC\left( \frac{2\xi_1^4 b^6}{a_1} + \frac{2\xi_2^4 Y_{\beta_2} b^6}{a_2} \right) \left( \frac{x_{\xi_1}^2 b^2}{a_1} + \frac{y_{\xi_1}^2 b^2}{a_2} \right)^2
\]

(3.32)

mulitplying the numerator and denominator of the RHS term of (3.32) by \((\frac{x_{\xi_1}^2 b^2}{a_1} + \frac{y_{\xi_1}^2 b^2}{a_2})\) and noting that \(a_1 = a_2 = a\) given \(\beta_1 \xi_1^2 = \beta_2 \xi_2^2\) the expression simplifies to

\[
\frac{TAC\left( \frac{2\xi_1^4 X_{\beta_1} b^6}{a} + \frac{2\xi_2^4 Y_{\beta_2} b^6}{a} \right) \left( \frac{x_{\xi_1}^2 b^2}{a} + \frac{y_{\xi_1}^2 b^2}{a} \right)^2 - TAC\left( \frac{2\xi_1^4 b^6}{a} + \frac{2\xi_2^4 Y_{\beta_2} b^6}{a} \right) \left( \frac{x_{\xi_1}^2 b^2}{a} + \frac{y_{\xi_1}^2 b^2}{a} \right)^2}{(\frac{x_{\xi_1}^2 b^2}{a} + \frac{y_{\xi_1}^2 b^2}{a})^2}
\]

(3.33)
and solves to the following
\[
TAC\left(\frac{(\beta_1 \xi_1 - \beta_2 \xi_2)2 \xi_1^2 \xi_2^2 Y^{1\xi}}{a}\right)
\left(\frac{X \xi_1^2 Y^2}{a} + \frac{Y \xi_2^2 Y^2}{a}\right)^2
\]
\[(3.34)\]

If \(\beta_1 \xi_1^2 = \beta_2 \xi_2^2\) it follows immediately that
\[
\frac{\partial q_{2ij}^*}{\partial \sigma_P^2} = 0
\]
\[(3.35)\]
such that (3.23) holds with equality \(\square\)

A corollary to proposition 3.1, is that if the change in the quota demands of fishers differ with respect to the level of uncertainty, then it must be true that the output of some fishers is greater and other fishers less at the new quota equilibrium. This is an original result as it had previously been accepted that the quota demand of fishers in an ITQ fishery would decrease with an increase in the variance of the output price [P. Andersen (1982) p. 24]. In the fishery example, if \(\beta_1 \xi_1^2 < \beta_2 \xi_2^2\) then
\[
\frac{\partial q_{1kt}^*}{\partial \sigma_P^2} > 0 > \frac{\partial q_{2jt}^*}{\partial \sigma_P^2}
\]
and increasing \(\sigma_P^2\) will increase (decrease) the equilibrium output of F1 (F2) fishers. Similarly, if \(\beta_1 \xi_1^2 > \beta_2 \xi_2^2\) then
\[
\frac{\partial q_{1kt}^*}{\partial \sigma_P^2} < 0 < \frac{\partial q_{2jt}^*}{\partial \sigma_P^2}
\]
and increasing \(\sigma_P^2\) will increase (decrease) the equilibrium output of F2 (F1) fishers.

This is an important result because it has been shown that in a competitive environment [Sandmo (1982), Ishii (1977)] that the output of a firm facing an uncertain output price will, ceteris paribus, be reduced given an increase in the variance of the random variable. A sufficient condition for this result is nonincreasing absolute risk aversion where absolute risk aversion is defined by (3.36) and nonincreasing absolute risk aversion by \(R_A(\Phi) \leq 0\).
\[
R_A(\Phi) = -\frac{U''(\Phi)}{U'(\Phi)} = \text{coefficient of absolute risk aversion}
\]
\[(3.36)\]
Chapter 3. Conceptual Framework

Nonincreasing absolute risk aversion implies that the risk premium should not increase as individuals become wealthier in terms of economic profit.

A mean-variance specification satisfies the condition of constant absolute risk aversion. From proposition 3.1, however, increasing $\sigma_p^2$ in an ITQ fishery may actually increase, leave unchanged, or decrease the output of heterogeneous fishers while leaving the total output of fishers unchanged. The difference between the two results is that in an ITQ fishery it is the quota demands that determine the optimal output of fishers. The quota demands are themselves a function of fishers' harvesting functions, input and output prices, and the quota price which itself is a function of the quota demands. As a result, the effect of an increase in uncertainty on fishers is dependent not only upon their actions but the actions of others. The effect of a change in uncertainty on the output of an individual fisher cannot be known, therefore, without knowing the expected utility functions of all other fishers. This will be true whether fishers have utility functions that exhibit increasing, constant, or decreasing absolute risk aversion. In a competitive market where firms face no constraints on their output, their optimum output is determined solely by solving the first order condition of their expected utility functions. In this case, the affect of uncertainty on a firms' optimum output will depend unambiguously upon the absolute risk aversion of its expected utility function.

Provided that (3.23) does not hold with equality and assuming the expected price under uncertainty equals the price with certainty, it has been shown that the short-run quota equilibrium will differ between the certainty and uncertainty situations. In the certainty situation where $\sigma_p^2 = 0$, fishers maximise their individual economic profits by choice of the quantity of fish they harvest and the quantity of quota traded. Given a competitive quota market with no externalities, it must be the case that the resulting equilibrium cannot be bettered in terms of total profits such that there can
be no other quota allocation that will result in a higher profit from the fishery. This result follows from the first fundamental theorem of welfare economics and implies that the short-run quota equilibrium with no uncertainty maximises the short-run rent in the fishery. Consider the following result.

**Proposition 3.2** Provided that private costs equal social costs, there exists a competitive quota market, and fishers maximise economic profits then for a given number of fishers of all types and a given TAC, the short-run ITQ quota equilibrium with no uncertainty and/or risk neutrality will maximise the expected short-run rent in the fishery.

**PROOF.** The expected short-run rent in the fishery may be written as follows

\[
\mathcal{E}\{\Pi_t\} = \left[\overline{P}Q_{1t} - \frac{CQ_{1t}^2}{\xi_1^2 b^2 X} - X f c_1\right] + \\
\left[\overline{P}(TAC - Q_{1t}) - \frac{C(TAC - Q_{1t})^2}{\xi_2^2 b^2 Y} - Y f c_2\right] 
\] (3.37)

where \( Q_{1t} = X q_{1kt} \), \( Q_{2t} = Y q_{2jt} = (TAC - Q_{1t}) \) and \( X \) and \( Y \) are given. Maximising with respect to \( Q_{1t} \) we obtain the following first order condition

\[
\frac{\partial \mathcal{E}\{\Pi_t\}}{\partial Q_{1t}} = -\frac{2C Q_{1t}}{\xi_1^2 b^2 X} - \frac{2C(Q_{1t} - TAC)}{\xi_2^2 b^2 Y} = 0 
\] (3.38)

Solving (3.38) with respect to \( Q_{1t} \)

\[
Q_{1t}^* = \frac{TAC(\xi_1^2 X)}{\xi_1^2 X + \xi_2^2 Y} 
\] (3.39)

To show that the total rent in the fishery is at a unique global maximum at \( Q_{1t}^* \) it is sufficient to show that

\[
\frac{\partial^2 \mathcal{E}\{\Pi_t(Q_{1t},\ldots)\}}{\left(\partial Q_{1t}\right)^2} = -\frac{2C}{\xi_1^2 b^2 X} - \frac{2C}{\xi_2^2 b^2 Y} < 0 
\] (3.40)
Dividing (3.39) through by $X$, the number of $F_1$ fishers, we obtain

$$q_{1kt}^* = \frac{TAC(\xi_1^2)}{\xi_1^2 X + \xi_2^2 Y}$$  \hspace{1cm} (3.41)

which can be shown to be identical to (3.19) or the quota demand of a $F_1$ fisher at the short-run quota equilibrium with no uncertainty. Similarly, solving for $q_{2jt}$ by substituting (3.39) into the expression $Q_{2t} = TAC - Q_{1t}$

$$Q_{2t}^* = \frac{TAC(\xi_1^2 X)}{\xi_1^2 X + \xi_2^2 Y}$$

$$= \frac{TAC(\xi_2^2 Y)}{\xi_1^2 X + \xi_2^2 Y}$$  \hspace{1cm} (3.42)

Dividing through by $Y$, the number of $F_2$ fishers, we obtain

$$q_{2jt}^* = \frac{TAC(\xi_2^2)}{\xi_1^2 X + \xi_2^2 Y}$$  \hspace{1cm} (3.43)

which can be shown to be identical to (3.20) or the quota demand of a $F_2$ fisher at the short-run quota equilibrium with no uncertainty $\square$

Proposition 3.2 is proved for the specific fishery model but applies generally to any ITQ fishery where there is a competitive quota market, no externalities, no uncertainty, and where the marginal cost curves of fishers are increasing with respect to output. In the case where $\sigma_P^2 > 0$ and the expected output price equals its value with no uncertainty, fishers maximise the expected utility of economic profits. In a mean-variance specification this is equivalent to fishers maximising expected economic profit less risk costs. By proposition 3.2 or the first fundamental theorem, ceteris paribus, the resulting equilibrium with $\sigma_P^2 > 0$ must generate an expected short-run rent equal to or less than the equilibrium with no uncertainty. Such a result is not the case in an open access fishery where the existence of a positive risk premium may reduce the difference between optimal effort and equilibrium effort and thereby
increase the expected rents in the fishery. The difference between the equilibrium with and without uncertainty where (3.23) does not hold with equality is explained by the marginal risk premium of fishers. In the case where fishers are risk neutral or where the resource owner bears the entire risk, the expected rent from the quota equilibrium where $\sigma_P^2 > 0$ will be the same as the equilibrium with no uncertainty irrespective of whether (3.23) holds with equality. In the case where (3.23) does hold with equality, it has been shown that an ITQ equilibrium with uncertainty and risk aversion will maximise the expected short-run rent in the fishery. This is an original result as it had previously been believed that a fixed producer price system, where the resource owner bears all the risk of output price fluctuations, was the only scheme capable of maximising the expected rent in a fishery.

As a corollary to proposition 3.2, if the rent in the fishery is a strictly concave function of the quota allocation to fishers then reducing the level of uncertainty as defined by $\sigma_P^2$ cannot decrease and will in general increase the expected rent from the fishery. This result is perfectly general because if the short-run rent is strictly concave in the quota allocation the quota equilibrium with no uncertainty must be a unique global maximum. Consequently, any change in the equilibrium must reduce the short-run rent. In the specific fishery model, if (3.23) does not hold with equality, the higher the value of $\sigma_P^2$ the greater will be the divergence from the short-run rent maximising quota equilibrium and hence the lower will be the expected rent. It follows, therefore, that a resource owner concerned with maximising the expected rents in a fishery or maximising the expected rents less the risk costs of fishers, a reduction in the level of uncertainty at zero cost will, ceteris paribus, unambiguously increase its objective function. Reducing uncertainty, ceteris paribus, will also increase the expected utility.

---

6 Hannesson (1984) made this observation while addressing the issue of fisheries management under uncertainty in an open access fishery.
of fishers and will in general increase the expected rent in the fishery. Consider the following result.

**Proposition 3.3** Provided that the total expected rent in an ITQ fishery is strictly concave in the quota allocation then increasing uncertainty cannot increase the expected rent and will in general decrease it.

**PROOF.** From proposition 3.2, the rent maximising quota allocation is defined as follows

\[
Q^*_t = \frac{TAC(\xi^t X)}{\xi^t X + \xi^2 Y} \tag{3.44}
\]

Defining \( \widehat{Q}_t = X\widehat{q}_t \) as the short-run quota equilibrium with uncertainty then from (3.12)

\[
\widehat{Q}_t = \frac{TAC(\xi^t X)}{\xi^t X + \frac{\xi^2 Y a_t}{a_2}} \tag{3.45}
\]

Given that \( a_1 = 2C + 2\xi^t X^2 \beta_1 \sigma^2 \) and \( a_2 = 2C + 2\xi^2 Y^2 \beta_2 \sigma^2 \), it follows immediately that if \( \beta_1 \xi^t = \beta_2 \xi^2 \) then \( a_1 = a_2 \) and

\[
\widehat{Q}_t = Q^*_t \tag{3.46}
\]

if \( \beta_1 \xi^t > \beta_2 \xi^2 \) then \( a_1 > a_2 \) and

\[
\widehat{Q}_t < Q^*_t \tag{3.47}
\]

and if \( \beta_1 \xi^t < \beta_2 \xi^2 \) then \( a_1 < a_2 \) and

\[
\widehat{Q}_t > Q^*_t \tag{3.48}
\]

Differentiating (3.45) with respect to \( \sigma^2 \)

\[
\frac{\partial \widehat{Q}_t}{\partial \sigma^2} = -\frac{TAC(\xi^t X)[(\beta_1 \xi^t - \beta_2 \xi^2)4C\xi^2 Y^4]}{(\xi^t X + \frac{\xi^2 Y a_t}{a_2})^2} \tag{3.49}
\]
It follows from (3.49) that if \( \beta_1 \xi_1^2 = \beta_2 \xi_2^2 \)
\[
\frac{\partial \bar{Q}_{1t}}{\partial \sigma_p^2} = 0 \tag{3.50}
\]
If \( \beta_1 \xi_1^2 > \beta_2 \xi_2^2 \)
\[
\frac{\partial \bar{Q}_{1t}}{\partial \sigma_p^2} < 0 \tag{3.51}
\]
and if \( \beta_1 \xi_1^2 < \beta_2 \xi_2^2 \)
\[
\frac{\partial \bar{Q}_{1t}}{\partial \sigma_p^2} > 0 \tag{3.52}
\]
Given that the expected rent is strictly concave in the quota allocation then it follows immediately from (3.46-3.48) and (3.50-3.52) that increasing uncertainty will decrease the expected rent in the fishery provided that \( Q^*_{1t} \neq \bar{Q}_{1t} \) and leave the expected rent unchanged if \( Q^*_{1t} = \bar{Q}_{1t} \).

From proposition 3.3., given that the expected rent in the fishery is strictly concave with respect to the quota allocation, increasing \( \sigma_p^2 \) cannot increase the expected rent. Similarly, reducing the uncertainty faced by fishers will not decrease and in general will increase the expected short-run rent. From the objective function of fishers, irrespective of whether the expected short-run rent is maximised, reducing the uncertainty faced by fishers will always increase their expected utility. An implication of proposition 3.3, therefore, is that given a risk neutral resource owner and risk averse fishers it is advantageous to reduce the uncertainty faced by fishers. Such risk sharing could take the form of a fixed output price payable to fishers at price equal to its expected value. Increasing the risk aversion of one or more of the fishers defined by \( \beta_1 \) or \( \beta_2 \) may, however, increase the total expected rent in the fishery. This surprising result arises from the fact that if (3.23) does not hold with equality then the expected rent maximising equilibrium defined by \( Q^*_{1t} \) will not arise. It follows, therefore, that
if $\beta_1 \xi_1^2 \neq \beta_2 \xi_2^2$ increasing or decreasing the risk aversion parameters of one or both of the fishers until (3.23) does hold with equality will change the quota equilibrium to where expected rents are maximised. The implication to a resource owner, therefore, is that reducing the uncertainty faced by all fishers for a given TAC will not decrease the expected rent from the fishery and in general will increase it. However, decreasing the risk costs of certain fishers and not others may increase or decrease the expected rents.

\section*{3.3 Fishery Rent}

Given that the short-run equilibrium allows for the existence of both types of fishers and because regulators are as concerned about the short run as they are about the long run or a first-best situation, the implications of rent capture methods are first addressed assuming the short-run quota distribution. To illustrate the differences between the short run and first best situation a numerical example of a fishery is presented that is consistent with the conceptual framework.

In the example it is assumed $\sigma_p^2 = 0$ and that the exogenous variables have the following values: $\overline{P} = 2$, $C = 3.2$, $r = 0.1$, $B = 10$, $\overline{b} = 20$, $f_c^1 = 80$, $f_c^2 = 40$, and $\xi_1 = 2$, $\xi_2 = 1$. Given no rent capture defined as $o_{kl} = o_{jl} = 0 \forall j, k$, the first-best problem can be solved by choosing the harvest for each type of fisher and total number of fishers of all types by solving an algorithm that maximises the sum of individual profits at each biomass level for different numbers of fishers of the two types. The global optimum is found by searching for the highest total profits over all biomass levels. The first-best solution with no uncertainty and with no rent capture is to set $b^* = 14$, $N^* = 6$, $M^* = 0$, $q_{ik}^* = 140 \forall k$, $q_{2j}^* = 0 \forall j$. This yields a total rent per time period, defined as the sum of the individual profits of fishers, of 720 monetary units.
This first-best solution with no uncertainty or rent capture requires that the biomass be 14 and that the total harvest of 840 quantity units per time period be caught by six F1 type fishers each harvesting 140 quantity units. Given no barriers to entry and exit, a competitive quota market, and that private costs equal social costs, the first-best solution should also be the long-run quota equilibrium. In the case of rent capture, the long-run quota equilibrium and first-best situation will differ because the individual fishers' maximisation problem will not internalise the rent collection costs of the resource owner.

In comparing the short run to the first-best it is assumed that the TAC under ITQ management is set equal to the first-best harvest level of 840 quantity units. Further, it is assumed that the TAC for the ITQ fishery of 840 quota units is allocated equally among both types of fishers who in total number no more than the number of fishers in the first-best solution. The amount allocated to individual fishers, however, has no effect on the market equilibrium and ultimate distribution of quota but does affect the cost/return to fishers from buying/selling or leasing quota. Under these conditions and using expression (3.21), the market price of quota is found to be some 1.71/unit. Solving for the short-run equilibrium with no uncertainty, each of the three F1 type fishers are found to harvest 224 units while each of the three F2 type fishers harvest 56 quota units. The marginal and average cost curves for the fishers are presented in Figure 3.1.

It is assumed that the 84 quota units that were obtained by the F1 type fishers were sold by the F2 fishers at an amount equal to the market price of quota multiplied by number of quota units. In an actual fishery, however, one would likely observe both outright purchases and leases of quota. At this equilibrium and prior to entry of other vessels, the total fishery rent per time period equals 552 monetary units or some 168 less than in the long-run or in the first-best situation without rent capture.
or uncertainty. Merely setting the TAC equal to the harvest level and allocating quota to the same total number of fishers as in the first-best solution is insufficient to ensure that the rent available in the short run will be the same. Putting aside the effects of uncertainty or the costs of rent capture, the rents in the short run and first-best solution will only coincide if the number and type of vessels at the time quota is first allocated in the fishery is the same as in the first best solution. For example, if the fishery at implementation of ITQ's had only six F1 type fishers then the first-best optimum would arise immediately since there would be no adjustment time required for entry and exit of vessels. On the other hand, if the initial conditions were such that there were three F1 and F2 type fishers, as in the above example, then the short-run and first-best equilibrium will differ.

Given the potential increase in welfare in moving from the short-run to the first-best, one may expect the distribution of quota to change over time as some vessels are retired and others added to the fishery. Provided there are perfect markets, no barriers to entry, and private and social costs are identical, then the first-best is achievable in the time necessary to allow for the entry and exit of all vessels. Where, however, market imperfections exist such as capital constraints on fishers wishing to build or buy new vessels or quota, the first-best optimum may never arise. Given such imperfections, the initial conditions of the fishery at implementation of ITQ's will have implications for rent capture in both the short and long-run.

Using the example, it is useful to present the profits, average profit per quota unit, and economic profits of fishers not including the costs/returns from buying/selling or leasing quota of the F1 and F2 fishers. These values are presented in Table 3.1 for each of the F1 and F2 fishers in addition to a total for the fishery under the assumption $\beta_1 = \beta_2 = 0$. The total profits are calculated by multiplying the number of F1 and F2 fishers at the short-run equilibrium by the profit for each type. The average profits are
the total profits of fishers divided by their harvests. Consulting Table 3.1, it can be seen that the F1 fishers have both higher total profits and average profits. The higher average profits earned by F1 fishers over and above that earned by F2 fishers may be viewed as intra-marginal rents that accrue from the particular harvesting technology that they employ. The expected per unit resource rent, assuming risk neutrality, is represented by the difference between the expected output price and the marginal harvesting cost of fishers at the equilibrium and is reflected in the quota price. It is, therefore, determined entirely by the marginal conditions of the optimising behaviour of fishers. In the case where fishers are risk averse, the expected resource rent will differ from the per unit quota price by an amount equal to a fisher’s marginal risk premium.

In examining the different rent capture methods, the maximum rent to be captured per period by the resource owner is set to be no more than total value of quota-holdings multiplied by a competitive rate of interest. In the case of risk neutrality or no uncertainty this will equal the annual resource rent in the fishery. The intra-marginal rent per quota unit in the fishery is defined as the difference in average profit per unit of fish harvested between the least and most profitable fishers. Given the assumption of identical fishing skills among fishers, intra-marginal rents in this fishery exist because of the technology employed by F1 fishers. Over time, as other fishers are able to adopt the more profitable F1 technology, the difference in profitability among fishers would disappear. In addition to resource and intra-marginal rents, there may be another rent that exists in the fishery in the short run. This rent, which may be termed a marginal quasi-rent, reflects the difference between the marginal fisher’s total rent and resource rent. It arises because there is a time lag between when ITQ management is introduced into the fishery and when other fishers can enter, purchase, and use quota. In the long run, this marginal quasi-rent would disappear because
other fishers entering the fishery would bid up the quota price until the marginal fisher was earning only a resource rent less any discounting because of risk.

Under the assumption that the earnings of fishers outside of the fishery are zero and noting that the marginal cost of production exceeds the average total costs for every fisher, the total rent in the fishery in the short run will, therefore, include an expected resource rent, an intra-marginal rent, and a marginal quasi-rent. The total expected rent is reflected in the expected total profits of fishers, the resource rent in the difference between the expected output price and marginal harvesting costs, the intra-marginal rent in the difference in average profitability between F1 and F2 fishers, and the marginal quasi-rent in the difference between expected total profits and the expected resource and intra-marginal rent. In the case where the average cost of some fishers exceeds their marginal cost at the quota equilibrium then the resource rent will exceed the total profits or total rent in the fishery. Such an equilibrium is possible in the short run where some fishers may be earning profits and others may be only covering their variable costs and a share of their fixed costs. The possibility that the resource rent may exceed the total profits in the fishery in the short run suggests, therefore, that an estimate be made of both the total profits of fishers and the resource rent in fishery prior to any rent capture.

The magnitude of the different rents in the short and long run in the fishery example are provided in Table 3.2 under the assumption of risk neutrality. A definition of the rents in the fishery with no uncertainty and positive profits for all fishers is provided in (3.53) under the assumption that fishers are price takers in both the output and factor markets.

\[
\text{Total Rent} = \text{Resource Rent} + \text{Intra-Marginal Rent} + \text{Marginal Quasi-Rent} \\
\sum_{i=1}^{n} (Pq_i - AC_i q_i) = (P - MC) \sum_{i=1}^{n} q_i + \sum_{i=1}^{n} [(\max(AC_i) - AC_i)q_i] +
\]
where \( n \) is the total number of fishers, \( AC_i \) is the average harvesting cost of fisher \( i \), \( MC \) is the marginal harvesting cost which is identical for all fishers at a quota equilibrium given risk neutrality or no uncertainty, \( \max(AC_i) \) is the average cost of the marginal fisher.

Consulting Table 3.1, F1 fishers have a higher average profit than F2 fishers at the short-run equilibrium. Both types of fishers continue to remain in the fishery because at the equilibrium their marginal value of an additional unit of quota is identical. In Table 3.2, the short-run rent in the fishery is shown to include a resource rent, an intra-marginal rent, and a marginal quasi-rent. The resource rent is reflected in the per unit difference between the output price and marginal harvesting costs multiplied by the total quota-holdings and represents some 26% of the total short-run fishery rent. The intra-marginal rents, earned exclusively by F1 fishers, accounts for some 43% of the short-run rent while the marginal quasi-rent accounts for some 30% of the total rent. Over time, as fishers are able to enter the fishery and adopt the F1 technology the quota price should rise to include the marginal quasi-rent. Given the assumption that the intra-marginal rents are due exclusively to the technology employed and not differential fishing skill then over time as the F1 technology is adopted the intra-marginal rents would also disappear. Eventually, the quota price would in a world of no uncertainty reflect the total rent per unit in the fishery.

### 3.4 Overview

Chapter 3 compares various methods of rent capture in a short-run equilibrium and compares the outcome to a first-best solution where a resource owner may choose the total harvest, number of fishers and their individual harvests per time period. In
case of no uncertainty and no rent capture, the short-run quota equilibrium is not found to be the same as the first-best solution. Merely setting the TAC equal to the first best harvest level and allocating quota to the same total number of fishers as in the first-best is insufficient to ensure the rent in the short run will be the same. The first-best and short run solution with no uncertainty or rent capture will only coincide when the number and type of vessels when quota are first allocated is the same as in the first-best solution.

The short-run rents in a fishery are also discussed and defined. It is noted that there may exist an intra-marginal rent defined on a per quota unit basis as the difference in average profit per unit of fish harvested between the least and most profitable fishers. A resource rent per quota unit represents the difference between the price and marginal cost of fishers at a quota equilibrium and is reflected in the quota price. A marginal quasi-rent which accrues to all fishers may also exist in the short run and on a per unit basis is the difference between the marginal fisher's total rent per unit and resource rent per unit.

Addressing the issue of uncertainty, it is found that, in general, changing the level of uncertainty as defined by \( \sigma_p^2 \) will change the short-run quota equilibrium. It is also shown that the optimal output of fishers will change depending upon how the quota demands of fishers change with respect to \( \sigma_p^2 \) and may increase, stay the same, or decrease. In a related result, is demonstrated that reducing the uncertainty faced by fishers for a given TAC will not decrease the expected rent from the fishery and in general will increase it. However, contrary to what one might expect, decreasing the risk costs of certain fishers and not others may increase or decrease the expected rent in the fishery.
Table 3.1: Short-run annual profits of F1 and F2 fishers prior to rent capture given risk neutrality

<table>
<thead>
<tr>
<th>Description</th>
<th>Profit</th>
<th>Quota-Holdings</th>
<th>Average Profit</th>
<th>Economic Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>163.2</td>
<td>224</td>
<td>0.73</td>
<td>139.2</td>
</tr>
<tr>
<td>F2</td>
<td>20.8</td>
<td>56</td>
<td>0.37</td>
<td>11.2</td>
</tr>
<tr>
<td>Total</td>
<td>552</td>
<td>840</td>
<td>0.66</td>
<td>451.2</td>
</tr>
</tbody>
</table>

Table 3.2: Annual fishery rents with no rent capture given risk neutrality

<table>
<thead>
<tr>
<th>Period</th>
<th>Resource Rent</th>
<th>Intra-marginal Rent</th>
<th>Marginal Quasi-rent</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Run</td>
<td>144</td>
<td>240</td>
<td>168</td>
<td>552</td>
</tr>
<tr>
<td>Long Run</td>
<td>720</td>
<td>0</td>
<td>0</td>
<td>720</td>
</tr>
</tbody>
</table>
Figure 3.1: Cost Curves of F1 and F2 Fishers
Chapter 4

Rent Capture Methods Reviewed

A pity only that the rent on land goes into private hands!


4.1 Introduction

Using the fishery model developed in chapter 3, seven methods of rent capture are reviewed including a quota rental charge, profit charge, net cash flow charge, an *ad valorem* royalty, lump sum fee, an auction/tender, and a quota transfer charge. Each method of rent capture is first examined individually along with a description of its principal features. A comparison is then made of the various methods by assessing their differential impact on fisher profits, distortions to efficiency, collection costs, and the risk costs of fishers. A discussion is also provided on the effects of rent capture under uncertainty.

To aid in the exposition, the fishery example provided in chapter 3 with given values for the exogenous variables is used to compare the effects of rent capture on fishers’ profits. In the comparison, it is assumed the resource owner captures rent at 100% and 50% of the total annual value of quota-holdings as measured by the quota price multiplied by the TAC and the interest rate. A rate of rent capture equal to...
100% of the total value of quota-holdings is, however, not a recommended practice since it may be desirable for the resource owner to have quota trade at a positive price.\(^1\)

### 4.2 Quota Rental Charge

A quota rental charge imposes a rental payment equal to some proportion of the quota price multiplied by a competitive rate of interest, i.e.,

\[
\text{Annual Rent Captured from Fisher } i,t = \alpha \Gamma_i r q_{it}
\]

where \(\alpha\) is the quota rental charge rate, \(\Gamma_i\) is the market price of quota per unit at time \(t\), \(r\) is the competitive rate of interest, and \(q_{it}\) is number of quota units owned at time \(t\) by fisher \(i\).

The quota rental charge attempts to collect a rental equal to a share of the annuity that would be earned if all quota owned were sold and the amount was invested outside the fishery at a competitive rate of interest. In a perfect quota market where fishers are price takers, have perfect foresight, the same planning horizon, a rate of time preference equal to the competitive rate of interest, and there is no uncertainty, a 100% quota rental charge should over time capture the entire resource rent in the fishery. In fisheries where such conditions do not exist, a quota price will not be a true reflection of the resource rent in the fishery. In the case of risk aversion and uncertainty the quota price will be less than the expected resource rent. Where there exists an uncompetitive quota market, the quota price will also be less than the per unit resource rent. Such a quota market may arise from oligopsonistic behaviour and barriers to entry into the fishery which penalises both sellers and lessors of quota. It

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\(^1\) Arnason (1989) has shown that under certain assumptions maximising the total value of quota in an ITQ managed fishery where quota is denominated as a share of the TAC will maximise the total fishery rent.
may also arise from an uneven distribution of risk costs among fishers. In such cases, the resource owner may capture less rent than desired from the fishery.

A feature shared by the quota rental charge with an auction or tender is that it is an \textit{ex-ante} method of rent capture. Because it is based upon the expectations of future net returns of fishers, it is possible for a quota rental charge to collect rent even when fishers are facing short-run losses due to adverse fluctuations in the fishery. Consequently, a quota rental charge can place a considerable burden on fishers in that short-run fluctuations in the fishery not reflected in the quota price are borne exclusively by fishers. In this sense, the quota rental charge fails to reduce the cost of risk faced by fishers. If it is the case that fishers are risk averse and the resource owner is risk neutral then there are potential welfare benefits from the sharing of risk between fishers and the resource owner.

In imposing a quota rental charge, the resource owner faces the choice of basing the rental on the pre-rental quota price or on the quota price following the announcement of rent capture in the fishery. If imposed on the pre-rental price then the resource rent collected each time period will not reflect any changes or fluctuations in the fishery. If imposed on the current quota price, the quota rental charge will vary with changes in the market’s expectation of future net returns in the fishery. Given that the current price would reflect the marginal profit to fishers net of the rental charge, the charge rate would necessarily have to be greater than if it was imposed on the pre-rental quota price. For example, a 100\% quota rental charge assessed on the quota price after announcement of rent capture by the resource owner would collect the same amount of rent as a 50\% rental charge assessed on the pre-rental quota price. The quota rental charges examined in this and other chapters assumes that the rental is imposed on the pre-rental price.

Another feature of a quota rental charge is the assignment of a “competitive rate
of interest” and a market price of quota in setting the rent charged. In deciding upon an appropriate rate of interest, the regulator must take care to avoid a rate that is too high such that more than the resource rent is collected and setting a rate too low such that less rent than desired is captured. If a resource owner wishes to reduce the risk of capturing more than the resource rent then assessment of the rental at a risk free rate of return may be desirable. In determining a quota price, it should be realised that prices can vary significantly over a fishing season and between bids [Lindner et al. (1989)]. On a practical basis, if quota prices are subject to considerable fluctuations some weighted average of quota prices on a regular basis may be desirable in terms of determining the rental charge.

4.3 Profit Charge

A profit charge captures rent at a fixed proportion of fisher profit and would be applied prior to any standard company profit taxes, i.e.,

\[
\text{Annual Rent Captured from Fisher } i,t = \begin{cases} 
\rho \theta_{it} & \text{if } \theta_{it} > 0 \\
0 & \text{otherwise}
\end{cases}
\]

where \( \rho \) is the profit charge rate and \( \theta_{it} \) is the profit of fisher \( i \) at time \( t \).

The profit charge proposed above would collect rent whenever profits are positive. Whenever profits are negative, the losses are borne exclusively by the fishers. It does not, therefore, represent a full loss offset profit charge where the resource owner pays out to fishers at the given charge rate whenever profits are negative. In determining the profit of fishers, the lease or purchase costs or interest payments on quota should not be treated as a deductible expense. This would ensure all fishers were treated equally in terms of their rental payments and avoid the possibility of fishers who were initially assigned quota gratis from selling their quota to a third party and then
leasing it back thereby reducing their tax liability.

The profit charge, unlike the quota rental charge, does not face the problem of deciding upon an appropriate rate of interest or quota price. It does, however, require that the resource owner know the individual earnings of fishers. Such information may be difficult and/or expensive to obtain. Further, in environments where there exist legal allowances such as accelerated depreciation or investment write-offs, the accounting profit of fishers may differ markedly from actual profits. There is also a potential problem that may arise out of the treatment of interest payments in the calculation of profits. If interest payments are deductible then those fishers who have purchased vessels or quotas with borrowed funds are relatively favoured over those who have financed such expenditures out of their own equity. The profit charge may, therefore, not be uniform in its effect across fishers.

The setting of an appropriate profit charge in multi-species fishery may also prove problematic. This is especially true in a multi-species fishery where a profit charge may collect rent from a subset of the species harvested. In such fisheries, separating expenses such as fixed costs among species would require arbitrary judgements by the regulator.

### 4.4 Net Cash Flow Charge

A net cash flow charge captures rent as a proportion of the net cash flow of fishers, i.e.,

\[
\text{Annual Rent Captured from Fisher } i,t = \begin{cases} 
\tau NCF_{it} & \text{given A1} \\
\tau \left[ NCF_{it} + \sum_{z=1}^{t-1} NCF_{iz} (1+r)^z \right] & \text{given A2} \\
0 & \text{otherwise}
\end{cases}
\]

**A1**: \( NCF_{it} > 0 \) and \( \sum_{z=1}^{t-1} NCF_{iz} (1+r)^z > 0 \).
A2 : \( \sum_{x=1}^{t-1} NCF_{ix}(1 + r)^x \leq 0 \) and \( NCF_{it} + \sum_{x=1}^{t-1} NCF_{ix}(1 + r)^x > 0 \).

where \( \tau \) is the net cash flow charge rate and \( NCF_{it} \) is the net cash flow of fisher \( i \) at time \( t \), \( \sum_{x=1}^{t-1} NCF_{ix}(1 + r)^x \) is the capitalised value of fisher \( i \)'s net cash flow until period \( t \).

The net cash flow of a fisher is defined as the total revenue from harvesting less cash expenditures excluding interest payments. Interest should not be considered as a deductible item since it would favour the operations of fishers with lower equity and higher debt load. Although similar to a profit charge, the net cash flow charge has some important differences. In keeping with Garnaut and Ross (1975) and their resource rent tax, positive cash flows would be charged at a predetermined rate while negative cash flows would be increased by a specified interest rate. Any capitalised negative cash flows would be subtracted from positive cash flows before any rent capture would take place. In proposing such a rental charge, Campbell and Haynes (1990) suggest that the rates of interest used to capitalise negative cash flows vary across fisheries. The greater riskiness of the fishery as measured in terms of uncertainty with respect to future returns and stock fluctuations then the greater the interest rate applied.

One problem with a net cash flow is its treatment of capital costs. In the case of vessels and gear already in the fishery, the net cash flow charge does not provide an allowance for depreciation or an opportunity cost for the value of the assets employed. Only when fishers purchase new gear or equipment is the net cash flow reduced by the capital expenditure. One way of addressing this problem is to allow for depreciated capital as a one-off expense when the rental scheme is first introduced [Campbell and Haynes (1990)]. Without such an allowance those fishers who undertake capital investments after the charge is imposed will be better off in terms of their rental
payments than identical fishers who purchased their vessel and gear before the charge was imposed. Another problem with a net cash flow charge, shared with a profit charge, is the separation of costs for individual species if fishers pay only a resource rent in a sub-set of the species. Imposing a net cash flow charge or a profit charge in a single species fishery may also prove difficult as unlike other rent capture methods, both require detailed cost and earnings information from individual fishers.

4.5 Ad Valorem Royalty Charge

The *ad valorem* royalty charge collects rent as a set percentage of the landed price of fish multiplied by the quota-holdings of fishers, i.e.,

\[
\text{Annual Rent Captured from Fisher } i, t = \mu P_t q_{it}
\]

where \( \mu \) is the *ad valorem* charge rate, \( P_t \) is the landed price of fish at time \( t \), and \( q_{it} \) is number of quota units owned at time \( t \) by fisher \( i \).

In an ITQ managed fishery where each fisher faces a binding quota constraint, assessment of the royalty on quota-holdings should approximate the actual landings of fishers. An advantage of imposing a royalty on quota-holdings rather than on landings is that it gives less incentive to fishers to misrecord their catches. One advantage with an *ad valorem* royalty is that it is relatively easy to implement and requires less information than a profit or net cash flow charge. In the case where fishers are risk averse and there exists random fluctuations in the output price, an *ad valorem* royalty also provides a means for risk sharing with the resource owner.

4.6 Lump Sum Fee

A lump sum fee collects rent from fishers by dividing the total amount of rent to be captured in the fishery by the number of fishers. The annual rent captured by the
resource owner is, therefore, identical over all fishers, i.e.,

\[
\text{Annual Rent Captured from Fisher } i,t = R_t/n_t
\]

where \( R_t \) is the total amount of rent collected by the resource owner and \( n_t \) is the total number quota-holders at time \( t \).

A feature of the lump sum fee is that each fisher pays the same rental to the resource owner irrespective of the quota-holdings and resource rent of fishers. Its principal advantage is the relative ease with which it may be applied in a fishery. It is for this reason that is a common method of cost recovery in a number of fisheries with limited entry or restrictive licensing.

### 4.7 Auction/tenders

An auction or tender of quota collects rent by selling a share of the TAC to individual fishers. An auction may allow quota-holders harvesting rights in perpetuity with full rights of resale or the resource owner may impose restrictions such as limiting the tenure to a given period of time with a subsequent auction/tender in future periods. A feature of an auction of individual quotas in a fishery is that the bidder would be required to specify both a price and quantity to be purchased. To aid in the bidding process, the bidders would be required to submit a minimum and maximum desired quantity of quota and a price that would be paid for the various quantities in between.

In auctioning quota, a resource owner faces the choice between a number of different types of auctions. These include an English, Dutch, first price sealed-bid, and second-price sealed bid auctions. Under the following assumptions, [McAfee and McMillan (1987)] the choice of the auction type will have no effect on the average rent captured.
1. Bidders are risk neutral.

2. Bidders appear the same to each other and the seller.

3. Bidders determine the value of their bids independently.

4. Payment is a function of the bid alone.

This revenue equivalence proposition is due to Vickrey (1961). Under these assumptions and given perfect foresight by fishers, an individual will bid an amount equal to the net present value of quota for the tenure of the quota, i.e.,

\[
\text{Rent Captured from Fisher } i = \sum_{t=1}^{T} \delta^{t} \theta_{it}
\]

where \( \delta^{t} \) is a discount factor, \( \theta_{it} \) is the profit for fisher \( i \) in period \( t \) for a given level of quota, and \( T \) is the tenure of the quota.

In an actual fishery, however, the assumptions for revenue equivalence are unlikely to hold. Fishers may be risk averse with respect to quota purchases and there may be considerable uncertainty with respect to the true value of the net returns in the fishery. In the case of uncertainty and risk averse individuals with competitive bidding, fishers will pay an amount in monetary terms no more than the discounted sum of the expected utility of their future profits for a given quantity.

\[
\text{Rent Captured from Fisher } i = \mathcal{E}\left\{ \sum_{t=1}^{T} \delta^{t} U(\theta_{it}) \right\}
\]

where \( \delta^{t} \) is a discount factor, \( U(\theta_{it}) \) is the utility of profit for fisher \( i \) in period \( t \) for a given level of quota, and \( T \) is the tenure of the quota.

The difference between the certainty and uncertainty cases is that in the former fishers can bid up to the discounted sum of their future profits, while in the latter they will bid up to discounted sum of their expected profits less risk costs. In the certainty
Chapter 4. Rent Capture Methods Reviewed

In this case, an auction has the potential of capturing the present value of any future resource rent, intra-marginal rent, and marginal quasi-rent. The capture of intra-marginal rent should, however, have no efficiency implications because any returns from innovation after the auction would accrue directly to the fisher. In a mean-variance specification and assuming the mean of the random variable equals the value with no uncertainty, the difference between the certainty and uncertainty cases would be entirely reflected in the discounted sum of the risk premium of fishers.

A concern common to all auctions is the up front costs and burden that such an ex-ante method of rent capture may impose on fishers. In the case of quota that is being auctioned in perpetuity, the bids may be several times greater than the expected annual profit of fishers. This may, in turn, penalise those fishers who face a greater borrowing constraint due to a high debt burden or little collateral. Similarly, companies who own several vessels or have more diversified interests may be better in overcoming any borrowing constraint and have an advantage in the auction process. In such cases, the successful bidders need not be those individuals with the highest valuation of the quota. To overcome this difficulty, auctions of quota may be given on a time limited tenure basis. In moving to time limited quotas, however, the nature of the property right is diminished. Uncertainty about future success in an auction may also limit investment that might otherwise take place. Another alternative to imposing high up-front costs on fishers is to impose both ex-ante and ex-post rent capture. In such a system, an additional method of rent capture, such as an ad valorem royalty, could be announced prior to the auction thereby reducing the net profits to fishers and their bid prices.

Another issue with an auction is that if fishers are risk averse, increasing uncertainty will reduce the bid price for quota. The greater the degree of risk aversion for a given level of uncertainty, the lower will be the price bid for quota by a fisher in
an auction. Similarly, the greater the uncertainty for a given level of risk aversion the lower will be the bid price. In the absence of capital constraints, the successful bidders for quota will, therefore, be those fishers with the highest expected profits less the costs of risk. Such fishers need not necessarily be individuals who earn the highest expected profits. Indeed, fishers who are highly specialised in a particular fishery may face greater risk costs reflected in a higher risk aversion parameter than diversified companies with interests in other economic activities. In using an auction to capture rent from a fishery, the less uncertainty faced by fishers, *ceteris paribus*, the greater will be the amount of rent collected. In this sense, it may be worthwhile for a risk neutral resource owner to take on the risk that would otherwise be faced by fishers. In the case of uncertainty with respect to the output price, this could take the form of auctioning the quota and arranging to pay fishers a fixed output price equal to its expected value.

### 4.8 Quota Transfer Charge

This method of rent capture imposes a burden only upon the seller or lessor of quota and collects rent equal to a share of the quantity of quota traded multiplied by the price at which it traded. It represents, therefore, a direct transfer from the seller or lessor of quota to the resource owner.

\[
\text{Annual Rent Captured by Resource Owner, } t = \eta \Gamma_t \psi_t + \zeta \gamma_t \omega_t
\]

where \(\Gamma_t\) is the average price paid for quota in perpetuity, \(\psi_t\) is the amount of quota sold, \(\gamma_t\) is the average lease price of quota, and \(\omega_t\) is the amount of quota leased in period \(t\), while \(\eta\) and \(\zeta\) are the transfer charge rates, respectively, on quota sold and leased.
The amount of rent captured with a quota transfer charge is dependent on the competitiveness of the quota market and the number of transfers. It shares a feature with the quota rental charge in that it is based on the quota price but differs in the respect that it is imposed only when quota is traded and leaves the returns in the fishery unchanged. A quota transfer charge, therefore, reduces the incentive for marginal fishers to exit the fishery but not the profits they may earn. Such a method of rent capture may, consequently, prevent more profitable operators from harvesting a greater share of the TAC. In the extreme, where \( \eta = \zeta = 1.0 \), there is no incentive for a marginal fisher to trade quota such that individual quota management will not lead to the Pareto efficient quota equilibrium. Such a situation is equivalent to having nontransferable individual quotas. Another problem with a quota transfer charge is actually collecting the rent with such a charge. In many fishery environments, it would be difficult to police the reported sale or lease price and relatively easy for a buyer and seller to agree to unreported payments to their mutual advantage.

4.9 Discussion

The seven methods of rent capture are assessed according to their effect upon the post-rent capture profits of fishers, their distortions upon the efficient operations of the fishery, their costs of rent collection and ability to capture rent, their ability to share risk between the resource owner and fishers, and their flexibility to adjust to changes in the rent. These issues are examined separately and where possible each method of rent capture is ranked according to the respective criteria. An overview of the different methods of rent capture according to the different criteria is then provided at the end of the chapter. To aid in the exposition, the fishery example presented in chapter 3 with defined values for the exogenous variables is used to compare the rent
capture methods with respect to the burden they impose on different fishers.

### 4.10 Profits of Fishers

An important consideration to a resource owner in selecting a method of rent capture is the differential effects on the profits of different fishers. Some methods may penalise smaller but not necessarily less profitable operators while others may collect proportionately less rent from one group of fishers than another.

To illustrate the issues, Tables 4.1 and 4.2 detail the profits and rent collected for various rent capture schemes for the F1 and F2 fishers assuming risk neutrality for all fishers and using the fishery example presented in chapter 3. The post-rental profits are calculated by subtracting from fisher profits the rental payment associated with the different methods of rent capture. In determining the rental payment for a net cash flow charge, it is assumed that the net cash flow of fishers equals their total revenue less variable costs. Under this assumption, the fixed costs of fishers may be viewed as an interest payment on capital employed in the fishery. It is further assumed that all quota is purchased/sold and that transactions take place at the post-rent capture price after announcement of the method and rate of rent capture.

Table 4.1 compares the post-rental profits of fishers given 100% collection of the annual value of quota-holdings while Table 4.2 compares post-rental profits of equivalent rent capture schemes under 50% rent capture.\(^2\) Observation of Tables 4.1 and 4.2 reveals that a quota rental charge imposes the same burden on F1 and F2 fishers as an *ad valorem* royalty and a net cash flow charge. In all three methods of rent capture and assuming risk neutrality, the F1 and F2 fishers are left, respectively, with annual profits of 124.80 and 11.20 given 100% capture of the resource rent. Under

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\(^2\)Any two or more methods of rent capture are said to be “equivalent” if they capture the same total amount of rent from the fishery.
50% rent capture, the three schemes leave F1 and F2 fishers with profits of 144 and 16 monetary units.

Provided that fishers face the same output price, an *ad valorem* royalty on the quota-holdings of fishers can be shown to always leave fishers with the same profits as an equivalent quota rental charge with or without uncertainty. This proposition is true for any fishery and not just for the specific model used in the thesis. Consider the following result.

**Proposition 4.1** At a short-run quota equilibrium if fishers face the same output price and charge rates then a quota rental charge and an equivalent *ad valorem* royalty on quota-holdings will leave fishers with identical profits.

**PROOF.** Equality of the rent captured by an *ad valorem* royalty and quota rental charge requires that

\[ \sum_{i=1}^{n} \mu P_{i} q_{i t} = \sum_{i=1}^{n} \alpha r_{i} q_{i t} \]  

(4.1)

Given that fishers face the same charge rates, output price, quota price, and interest rate (4.1) simplifies to

\[ \mu P_{i} = \alpha r_{i} \]

It follows immediately

\[ \mu P_{i} q_{i t} = \alpha r_{i} q_{i t}, \forall i \]  

(4.2)

where the LHS of (4.2) is the rent paid with an *ad valorem* royalty and the RHS is the rent paid with a quota rental charge. 

Equivalency between the net cash flow charge and quota rental charge as shown in Table 4.1 and 4.2, however, is not a general result and arises from the specific
characteristics of the harvest functions given in the fishery example. In the specific
fishery example with no uncertainty, it can be shown that the ratio of the output of
the F1 to F2 fishers at the quota equilibrium is the same as the ratio of their variable
costs and equals the ratio of the catchability coefficients squared. It follows, therefore,
that the ratio of the net cash flow of fishers will equal this same ratio and will also
equal the ratio of the value of quota-holdings of the F1 to F2 fishers. This implies
that the proportion of the value of quota-holdings to net cash flow is the same for
each fisher. Consider the following result.

**Proposition 4.2** At the short-run quota equilibrium without uncertainty, the ratio
of the quota demands of F1 and F2 fishers equals the ratio of the variable costs of F1
and F2 fishers and equals the ratio of the catchability coefficients squared of F1 and
F2 fishers. It follows that the ratio of the value of quota-holdings to net cash flow is
the same for F1 and F2 fishers.

**Proof.** The quota demands of F1 and F2 fishers with no uncertainty are as follows

\[ q_{1kt} = \frac{\xi_1^2(TAC)}{\xi_1^2 X + \xi_2^2 Y} \quad (4.3) \]

\[ q_{2jt} = \frac{\xi_2^2(TAC)}{\xi_1^2 X + \xi_2^2 Y} \quad (4.4) \]

The variable costs of F1 and F2 fishers are as follows

\[ VC_1 = \frac{C q_{1kt}^2}{\xi_1^2 b^2} \quad (4.5) \]

\[ VC_2 = \frac{C q_{2jt}^2}{\xi_2^2 b^2} \quad (4.6) \]

Dividing (4.3) by (4.4) and dividing (4.5) by (4.6)

\[ \frac{q_{1kt}}{q_{2jt}} = \frac{VC_1}{VC_2} = \frac{\xi_1^2}{\xi_2^2} \quad (4.7) \]
From (4.7), the net cash flow of F1 and F2 fishers may be written as follows

\[ NCF_1 = \bar{P}_{q_{1kt}} - VC_1 \]  (4.8)

\[ NCF_2 = [\bar{P}_{q_{1kt}} - VC_1] \frac{\epsilon_2}{\epsilon_1^2} \]  (4.9)

From (4.7), the annual value of quota-holdings of F1 and F2 fishers is as follows

Annual Value Quota-Holdings F1  =  \Gamma_trq_{1kt}  \quad (4.10)

Annual Value Quota-Holdings F2  =  [\Gamma_trq_{1kt}] \frac{\epsilon_2}{\epsilon_1^2}  \quad (4.11)

It follows immediately from (4.8-4.9) and (4.10-4.11) that the ratio of the value of quota-holdings to net cash flow is identical for both fishers.

If the value of quota-holdings to net cash flow is the same for all fishers, irrespective of the harvesting functions of fishers, then the rent paid in either a net cash flow charge or quota rental charge will be identical. Consider the following result.

**Proposition 4.3** If the individual value of quota-holdings of fishers as a proportion of the net cash flow is the same for all fishers then a net cash flow charge and an equivalent quota rental charge will leave fishers with identical profits.

**PROOF.** Equivalency of a net cash flow charge to a quota rental charge requires that

\[ \tau \left[ \sum_{i=1}^{n} (P_{tq_{it}} - C_{i}(q_{it})) \right] = \alpha \left[ \sum_{i=1}^{n} \Gamma_{t}r_{q_{it}} \right] \]  (4.12)

Rearranging (4.12)

\[ \frac{\tau}{\alpha} = \frac{\sum_{i=1}^{N} \Gamma_{t}r_{q_{it}}}{\sum_{i=1}^{N} (P_{tq_{it}} - C_{i}(q_{it}))} \]

Provided that the value of quota-holdings as a proportion of net cash flow is the same for every fisher then the following must hold

\[ \frac{\tau}{\alpha} = \frac{\sum_{i=1}^{N} \Gamma_{t}r_{q_{it}}}{\sum_{i=1}^{N} (P_{tq_{it}} - C_{i}(q_{it}))} = \frac{\Gamma_{t}r_{q_{it}}}{(P_{tq_{it}} - C_{i}(q_{it}))}, \forall i \]  (4.13)
which implies

\[ \tau(P_t q_{it} - C_t(q_{it})) = \alpha r_t q_{it}, \forall i \]  

(4.14)

where the LHS of (4.14) is the rental paid with a net cash flow charge and the RHS is the rental paid with a quota rental charge.

In general, if the value of quota-holdings as a proportion of net cash flow for a fisher is higher than the average for the fishery then an individual will pay proportionately more with a quota rental charge than an equivalent net cash flow charge. Similarly, if the value of quota-holdings as a proportion of the net cash flow is less than the average for the fishery, a fisher will pay proportionately more with an equivalent net cash flow charge. The net cash flow charge will, therefore, tend to be preferred by those fishers whose net cash flow earnings per quota unit are less than the average for the fishery. Conversely, those fishers with higher than average net cash flow earnings per quota unit will prefer a quota rental charge. To the extent that net cash flow earnings per quota unit are a measure of average profitability, so-called highliners will prefer a quota rental charge over a net cash flow charge.

In the fishery example, the post-rental profits of fishers are the same with a quota rental charge, net cash flow charge, and ad valorem royalty if all three schemes collect the same total amount of rent from the fishery. Such a result, however, does not hold for a profit charge or a lump sum fee. Observation of Tables 4.1 and 4.2 reveals that fishers who earn higher average profits per unit of fish harvested (F1) will prefer a quota rental charge over a profit charge. For example, at 50% rent capture of the annual value of quota-holdings, F1 fishers pay 21.29 with a profit charge and 19.20 monetary units with a quota rental charge. In comparison, F2 fishers pay, respectively, 2.71 and 4.8 monetary units under a profit and quota rental charge. Consequently, F2 fishers pay proportionately more rent with a quota rental charge than an equivalent
profit charge while F1 fishers pay proportionately less rent with a quota rental charge than a profit charge. This result is completely general: provided that a fisher earns a higher profit per quota unit than another, the fisher will pay proportionately less rent with a quota rental charge than with an equivalent profit charge than a fisher with a lower profit per quota unit. Consider the following result.

**Proposition 4.4** *Fishers with a higher average profit per unit of quota will pay proportionately less with a quota rental charge than with an equivalent profit charge in comparison to a fisher with a lower average profit per unit of quota.*

**PROOF.** Equality of the rent captured by profit charge and quota rental charge requires that

\[ \frac{\rho \sum_{i=1}^{n} \theta_{it}}{\alpha \sum_{i=1}^{n} \Gamma_{t} r q_{it}} = \alpha \left[ \sum_{i=1}^{n} r q_{it} \right] \]

(4.15)

Defining the average profit per quota unit by fishers which satisfies (4.15) as

\[ \frac{\theta_{1t}}{q_{1t}} > \frac{\theta_{2t}}{q_{2t}} > \ldots > \frac{\theta_{nt}}{q_{nt}} \]

Multiplying by

\[ \frac{\rho}{\alpha \Gamma_{t} r} \]

we obtain

\[ \frac{\rho \theta_{1t}}{\alpha q_{1t} \Gamma_{t} r} > \ldots > \frac{\rho \theta_{nt}}{\alpha q_{nt} \Gamma_{t} r} \]

where the numerator is the rental paid with a profit charge and the denominator is the rental paid with a quota rental charge.

Consulting Tables 4.1 and 4.2, it can be seen that the F1 fishers pay the least amount of rent with a lump sum fee than with any other method of rent capture.
Conversely, F2 fishers pay the greatest amount of rent with a lump sum fee. This difference arises from the proportion of the total quota owned by the respective fishers relative to the proportion they represent of the total fleet. For example, the proportion of the total quota owned by individual F1 and F2 fishers is, respectively, 0.267 and 0.067. Each F1 and F2 fisher, however, represents 0.167 of the total number of fishers such that F1 fishers would pay less with a lump sum fee than a quota rental charge while F2 fisher would pay more. This result is completely general and applies to any fishery. Consider the following.

**Proposition 4.5** Individual fishers who own a share of the TAC that exceeds the proportion of the rent paid per fisher with a lump sum fee will pay proportionately less with a lump sum fee than with an equivalent quota rental charge.

**PROOF.** The rent paid, as a proportion of the total rent captured, by fisher \(i\) with a quota rental charge is

\[
V_{it} = \frac{q_{it}}{\sum_{i=1}^{n} q_{it}}
\]

The rent paid, as a proportion of the total rent captured, by fisher \(i\) with a lump sum fee is

\[
W_{it} = \frac{1}{n}
\]

where \(n\) is the number of quota-holders or those persons liable for a lump sum fee charge at time \(t\). It follows immediately that if \(V_{it} > W_{it}\) then a fisher \(i\) will prefer a lump sum fee over an equivalent quota rental charge \(\Box\)

A lump sum fee can also be shown to be preferred over a profit charge by those fishers who have a higher than average level of profits. Such fishers would pay rent in the same proportion as fishers with low average profits with a profit charge but
would pay proportionately less in an equivalent rent capture scheme that charges every fisher the same amount.

A lump sum fee by forcing every fisher to pay the same rental irrespective of quota-holdings or profits, has the ability, therefore, to capture more than just rent from certain fishers. Consulting Table 4.1, it can be seen that a lump sum fee that collects an amount equal to 100% of the annual value of quota-holdings leaves F2 fishers with after-tax losses of 3.20 monetary units. At this same rate of rent capture, F1 fishers retain some 38% of the annual value of their individual quota-holdings.

A method of rent capture not presented in Tables 4.1 and 4.2 is the quota transfer charge. An equivalent comparison with such a rent capture method is not possible because it is unable to collect the same total amount of rent from the fishery as the other schemes. The imposition of a quota transfer charge has the effect of changing both the quota equilibrium and the quota price. For example, noting that F1 (F2) fishers are buyers (sellers) of quota, one may use (3.19) and (3.20) to solve for the quota demands of fishers with a quota transfer charge rate and $\beta_1 = \beta_2 = 0$:

\[
\frac{q_{1kt}}{q_{2jt}} = \frac{\xi_1 b^2 [P - \Gamma r]}{2C} \quad (4.16)
\]
\[
\frac{q_{2jt}}{q_{2jt}} = \frac{\xi_2 b^2 [P - (1 - \zeta) \Gamma r]}{2C} \quad (4.17)
\]

where $q_{1kt}$ and $q_{2jt}$ are, respectively, the quota demands of F1 and F2 fishers facing a quota charge rate of $\eta = \zeta$ in the interval $(0 - 1)$. Assuming risk neutrality or no uncertainty the quota price solves to the following:

\[
\Gamma_t = \frac{P[X\xi_1^2 + Y\xi_2^2]b^2 - 2C(TAC)}{[X\xi_1^2 + (1 - \zeta)Y\xi_2^2]b^2r} \quad (4.18)
\]

Substituting (4.18) into (4.16) and (4.17) and differentiating with respect to the
charge rate reveals that the quantity harvested by F1 (F2) fishers is decreasing (increasing) with respect to the charge rate. Consider the following result.

**Proposition 4.6** An increase in the quota transfer charge rate in the closed interval \([0 - 1]\) will increase (decrease) the output of F2 (F1) fishers.

**Proof.** Given \(\Gamma_t > 0\) it follows from \((4.18)\)

\[
\frac{\partial \Gamma_t}{\partial \zeta} = \frac{Y \xi_2^2 b^2 r [P b^2 (X \xi_1^2 + Y \xi_2^2) - 2C(TAC)]}{(X \xi_2^2 b^2 r + (1 - \zeta) Y \xi_2^2 b^2 r)^2} > 0 \tag{4.19}
\]

It follows from \((4.16)\)

\[
\frac{\partial \xi_{tt}}{\partial \zeta} = -\frac{\xi_1^2 b^2 r}{2C} < 0 \tag{4.20}
\]

It follows from \((4.17)\)

\[
\frac{\partial \xi_{2t}}{\partial \zeta} = \frac{\xi_2^2 b^2 r [\zeta - 1] (\frac{\partial \Gamma_t}{\partial \zeta}) + \Gamma_t}{2C} \tag{4.21}
\]

Substituting \((4.18)\) and \((4.19)\) into the expression \([\zeta - 1] (\frac{\partial \Gamma_t}{\partial \zeta}) + \Gamma_t\) we obtain

\[
[(\zeta - 1) (\frac{\partial \Gamma_t}{\partial \zeta}) + \Gamma_t] = \frac{\Gamma_t X \xi_1^2}{X \xi_1^2 + (1 - \zeta) Y \xi_2^2} > 0 \tag{4.22}
\]

Substituting \((4.22)\) into \((4.21)\) it follows immediately that \(\frac{\partial \xi_{2t}}{\partial \zeta} > 0 \square\)

At any quota transfer charge rate greater than zero, therefore, the quota equilibrium will differ from the Pareto efficient quota equilibrium. In the extreme case where the charge rate is set at 100% of the quota price, the F2 fishers would optimise by setting their marginal cost plus a marginal risk premium equal to the expected output price. In the case of risk neutrality for all fishers, the quota equilibrium would have each F2 fisher selling 78.75 quota units and harvesting 61.25 quota units. Assuming the quota traded was sold by F2 fishers at the quota price given by \((4.18)\), the quota transfer charge would collect in total some 506 monetary units. At this equilibrium,
each F2 fisher would earn profits of 21.25 monetary units per time period and the output price would equal their marginal cost. Correspondingly, F1 fishers would harvest only 218.75 quota units and earn profits of 162.19 monetary units. The total rent in the fishery in the short run would be 550.31 monetary units, a reduction of 1.69 monetary units over the equilibrium without a quota transfer charge.

The final method of rent capture to be examined is an auction of quota. Given risk neutrality, an auction under certain conditions is able to capture the present value of expected profits. In an annual auction of the entire TAC of 840 quota units, an auction should capture 552 monetary units, an amount equal to the total profit in the fishery. This is substantially more than the 144 monetary units captured with a 100% quota rental charge, an amount equal to the expected resource rent in the fishery. Only in the case where marginal cost equals average cost for every fisher would a quota rental charge and an auction capture the same amount of rent from the fishery. In general, this condition will only arise in the long run after the passage of sufficient time to allow for full adjustments in the fishery and entry and exit of all vessels.

In reviewing the effects of rent capture on fishers it is important to consider both the annual profits and gain/loss from quota trading of fishers. To aid in the analysis, Table 4.3 presents the gain/loss from quota trading assuming all quota is sold/purchased in the first period after announcement of the type and rate of rent capture. In comparing the gains/losses from quota trades, it is useful to examine the different impacts of different methods of rent capture on the quota price.

The methods of rent capture that affect the quota price the most for a given amount of rent collected are a quota rental charge and an *ad valorem* royalty. In a quota rental charge, each percentage increase in the charge rate on the pre-rent capture quota price reduces the quota price by one percent. Provided that an *ad
valorem royalty collects the same amount of rent as a quota charge, it will also have the same affect upon the quota price. In the case of a profit or net cash flow charge, the quota price after rent capture is, respectively, \((1-\rho)\) and \((1-r)\) multiplied by the pre-rent capture quota price. Whenever the annual value of quota-holdings is less than the total profits or total net cash flow of fishers, then the charge rate for a quota rental charge will be greater than that for an equivalent profit charge or net cash flow charge. It follows, therefore, that if \(\rho\) or \(r\) are less than the quota rental charge rate \(\alpha\), the post-rent capture quota price will be higher than with a quota rental charge. The rent capture method that does not change the quota price is a lump sum fee. This is because a lump sum fee will be treated as a fixed cost by fishers and would not be accounted for in a quota price that reflects the marginal conditions in the fishery.

Those methods of rent capture that reduce the quota price the least will, therefore, tend to benefit those fishers who sell or lease out their quota. Consulting Table 4.3, therefore, a lump sum fee is the least (most) preferred method of rent capture in terms gains/losses from quota-trading for F1 (F2) fishers. In descending order of preference in terms of quota trading only, F1 fishers would prefer a quota rental charge and \(ad valorem\) royalty, profit charge, net cash flow charge, and lump sum fee. F2 fishers would have a reverse ordering, preferring the lump sum fee the most and quota rental charge the least in terms of the gains from quota-trading.

4.11 Distortions to Efficiency

A fundamental feature of ITQs given a competitive quota market, zero transactions costs, private costs equal social costs, perfect information, and no restrictions on exit or entry or on the sale or lease of quota is that the resulting equilibrium allocation
should be Pareto efficient for the given TAC.\textsuperscript{3} If this was not the case, it would imply that at a quota equilibrium there would be gains to be made from trade. An important consideration in capturing rent, therefore, is to ensure that the Pareto efficient quota allocation does not change and that no distortions are introduced into the fishery.

In comparing the different methods of rent capture where the annual value of quota-holdings is equal to or less than the total profit of fishers, it can be shown with the specific fishery model that a lump sum fee charge and a quota transfer charge can alter the Pareto efficient allocation while still collecting an amount no more than the total value of quota-holdings. In the case of the lump sum fee applied uniformly to all fishers, the rental paid by each fisher is unrelated to their individual earnings or quota-holdings. It has the potential, therefore, of penalising fishers who have relatively small quota-holdings but who may be no less profitable than other fishers. In the specific fishery example, a lump sum fee that collects in total 144 monetary units, an amount equal to the annual value of quota-holdings, would charge a rental to each fisher of 24 monetary units. At this charge rate, however, F2 fishers would face losses of 3.2 monetary units per time period. Such fishers would, therefore, be obliged to exit the fishery resulting in a new short-run quota equilibrium. The total rent in the fishery and quota-holdings of fishers before and after the introduction of such a lump sum fee are presented in Table 4.4.

At the new equilibrium with a lump sum fee, each F1 fisher would harvest 245 quota units and earn a pre-tax profit of 165 monetary units. Assuming the same amount of rent is collected from the fishery then each of the F1 fishers upon the departure of the F2 fishers would pay 48 monetary units per time period for the privilege of leasing the quota from an F2 fisher. In total, the rent in the fishery at the

\textsuperscript{3}It should be noted that ITQs can deal with the problem of stock externalities but not with externalities that arise from the "... interference of each vessel with other vessels' fishing operations" [Clark (1980)].
new equilibrium would be some 495 monetary units or a reduction of 57 monetary units over the Pareto efficient quota equilibrium. Observation of Table 4.4 also reveals that at the new equilibrium, 105 units of quota would be unused such that the TAC would no longer be binding on the fishery. Over time with no barriers to entry or capital constraints on fishers, additional F1 fishers should enter the fishery attracted by the positive profits. Eventually, the total rent in the fishery should rise to the long-run equilibrium level.

A quota transfer charge may also change the optimal allocation of quota. The effects of a 100% quota transfer charge in the specific fishery model are provided in Table 4.5. It can be seen that by eliminating the gains from trade to fishers but not the returns from the fishery, those fishers (F2) that would otherwise have sold or leased their quota-holdings may choose to use the quota themselves. For example, in the absence of a quota transfer charge each fisher will maximise their expected utility given a mean-variance specification by setting the annual quota price equal to the expected output price less marginal harvesting costs and less the marginal risk premium. Under a 100% quota transfer charge, however, F2 fishers no longer attach an opportunity cost to owning quota and will maximise their profits by setting the expected output price equal to the marginal cost plus the marginal risk premium. Given increasing marginal cost, this implies F2 fishers will harvest more with a quota transfer charge than without. The result is a change to the Pareto efficient quota allocation and consequently a reduction in the total expected rent in the fishery.

Under risk neutrality, a quota rental charge, profit charge, net cash flow charge, and *ad valorem* royalty will not change the Pareto efficient quota equilibrium provided that no more than the expected resource rent is collected from the fishery and that fishers exit the fishery when they face negative economic profits. In the case of uncertainty and risk averse behaviour by fishers this may not be true such that a
change in the charge rate may indeed change the short-run quota equilibrium. Before addressing the problem of charge rates and their effect on optimal output levels, it is useful to present some results in the literature. Assuming that fishers maximise the expected utility of economic profits and that their utility functions are bounded from above and twice differentiable then the following types of risk aversion may be defined.\footnote{Arrow (1984), chapter 9, provides a review of the theory of risk aversion.}

$$R_A(\Phi) = -\frac{\mu'(\Phi)}{U(\Phi)} = \text{coefficient of absolute risk aversion} \quad (4.23)$$

$$R_R(\Phi) = -\frac{\Phi \mu'(\Phi)}{U(\Phi)} = \text{coefficient of relative risk aversion} \quad (4.24)$$

where $U(\Phi)$ is the utility of economic profit, decreasing (increasing) absolute risk aversion is defined by $R_A(\Phi) < 0$ ($R_A(\Phi) > 0$), decreasing (increasing) relative risk aversion is defined by $R_R(\Phi) < 0$ ($R_R(\Phi) > 0$).

In the literature, the concepts of absolute and relative risk aversion are normally applied to individuals whose utility functions are a function of their wealth. Arrow (1984) has argued that individuals have increasing relative risk aversion and decreasing absolute risk aversion. The former implies that persons willingness to accept a bet will decrease if the size of the bet and their wealth increase in the same proportion. There is conflicting evidence whether this is observed empirically although Arrow argues there are theoretical reasons for making this assumption. Decreasing or at least nonincreasing absolute risk aversion implies that as individuals become wealthier the risk premium defined as the difference between the expectation of the return and its certainty equivalent should not increase.

A result due to Sandmo (1971) is that increasing the tax rate of a full loss offset profit tax rate under uncertainty will cause a firm's output to increase, stay constant, or decrease according to whether relative risk aversion is increasing, constant, or
decreasing. In the case of an ITQ fishery, a change in any charge rate on the output of fishers is dependent upon both its direct effect on quota demands and indirect effects on the level of uncertainty and quota price. As a corollary to proposition 3.1, provided that the change in the quota demands of fishers from a change in the charge rate is the same for all fishers then for a given TAC the quota equilibrium is unchanged with a change in the charge rate. This requires that

$$\frac{\partial q_k(.)}{\partial c_l} = \frac{\partial q_j(.)}{\partial c_l} = 0 \forall k, j$$

(4.25)

where $q_i$ is the quota demand of fisher $i$ which is a function of the charge rate $c_i$, the level of uncertainty which may itself be a function of $c_i$, the harvesting function of the fisher, expected input and output prices and the quota price which is itself a function of the charge rate and level of uncertainty. Provided that (4.25) holds with equality irrespective of the level of relative risk aversion, a change in the charge rate will not change the outputs of fishers at the equilibrium.

In the mean-variance specification, the condition that ensures a change in the charge rate of any of the methods of rent capture will leave the quota equilibrium unchanged is given by (4.26).

$$\beta_1 \xi_1^2 = \beta_2 \xi_2^2$$

(4.26)

In the case of a quota rental charge, irrespective of whether (4.26) holds with equality or not, a change in the charge rate will leave the quota equilibrium unchanged. This is because with a quota rental charge the quota demands are not a function of the charge rate and the level of uncertainty is the same whatever the charge rate.

Given positive profits and net cash flows, the risk costs of fishers under the different charge rates can be solved for a profit charge and net cash flow charge as per (3.8). It can be shown that under this condition, with uncertainty with respect to output
and input prices, the risk costs of fishers are reduced to the square of one minus the charge rate multiplied by the variance of economic profit. In the case where fishers face uncertainty only with respect to the output price, an *ad valorem* royalty will also reduce the risk costs of fishers. Where the uncertainty faced by fishers is not with respect to the output price, an *ad valorem* royalty will leave the risk costs of fishers unchanged. In this case and provided that the quota price remains positive, the quota equilibrium will be unchanged for any *ad valorem* charge rate. This is because the quota demands of fishers with an *ad valorem* charge rate will only change if the level of uncertainty changes with the charge rate.

In the case where (4.26) does not hold with equality and the uncertainty is with respect to the output price, a change in the rate of a profit charge, net cash flow charge, and an *ad valorem* royalty will change the quota equilibrium. Given positive profits and net cash flow each period then, if $\beta_1 \xi_1^2 > \beta_2 \xi_2^2$, an increase in the charge rate will increase (decrease) the output of F1 (F2) fishers. In the case where $\beta_1 \xi_1^2 < \beta_2 \xi_2^2$ an increase in the charge rate will decrease (increase) the output of F1 (F2) fishers. It can also be shown that increasing the charge rate if (4.26) does not hold with equality will increase the expected rents in the fishery provided that the expected rents are strictly concave in the quota allocation. Consider the following

**Proposition 4.7** *Given that the expected rent is strictly concave in the quota allocation, the uncertainty faced by fishers is only with respect to the output price, and that $\beta_1 \xi_1^2 = \beta_2 \xi_2^2$ then increasing the charge rate of a profit or net cash flow charge will leave the output of all fishers and the expected rent in the fishery unchanged. If $\beta_1 \xi_1^2 > \beta_2 \xi_2^2$ then an increase in the charge rate will increase (decrease) the output of F1 (F2) fishers and increase the expected rent in the fishery. If $\beta_1 \xi_1^2 < \beta_2 \xi_2^2$ then an increase in the charge rate will decrease (increase) the output of F1 (F2) fishers and*
increase the expected rent in the fishery.

PROOF. The quota demands of F1 and F2 fishers with a profit charge of \( \rho \) in the closed interval \([0, 1]\) are as follows,

\[
\widetilde{q}_{1kt} = \frac{\xi_1^2(TAC)}{X \xi_1^2 + Y \xi_2^2 + \frac{Y \xi_2^2 d_1}{d_2}} \tag{4.27}
\]

\[
\widetilde{q}_{2jt} = \frac{\xi_2^2(TAC)}{X \xi_1^2 + Y \xi_2^2} \tag{4.28}
\]

where

\[
d_1 = 2C(1 - \rho) + 2\beta_1(1 - \rho)^2 \sigma_p^2 \xi_1^2 b^2
\]

and

\[
d_2 = 2C(1 - \rho) + 2\beta_2(1 - \rho)^2 \sigma_p^2 \xi_2^2 b^2.
\]

Replacing the profit charge rate \( \rho \) by a net cash flow charge rate \( \tau \) in (4.27) and (4.28) will yield the quota demands with a net cash flow charge. From proposition 3.2, the quota demands of F1 and F2 fishers without rent capture and without uncertainty maximise the short-run rent in the fishery for given number of F1 and F2 fishers and are as defined follows

\[
q_{1kt}^* = \frac{\xi_1^2(TAC)}{X \xi_1^2 + Y \xi_2^2} \tag{4.29}
\]

\[
q_{2jt}^* = \frac{\xi_2^2(TAC)}{X \xi_1^2 + Y \xi_2^2} \tag{4.30}
\]

It follows that if \( \beta_1 \xi_1^2 = \beta_2 \xi_2^2 \) then \( d_1 = d_2 \) and

\[
\widetilde{q}_{1kt} = q_{1kt}^* \tag{4.31}
\]

\[
\widetilde{q}_{2jt} = q_{2jt}^* \tag{4.32}
\]

If \( \beta_1 \xi_1^2 > \beta_2 \xi_2^2 \) then \( d_1 > d_2 \) and

\[
\widetilde{q}_{1kt} < q_{1kt}^* \tag{4.33}
\]

\[
\widetilde{q}_{2jt} > q_{2jt}^* \tag{4.34}
\]

If \( \beta_1 \xi_1^2 < \beta_2 \xi_2^2 \) then \( d_1 < d_2 \) and

\[
\widetilde{q}_{1kt} > q_{1kt}^* \tag{4.35}
\]

\[
\widetilde{q}_{2jt} < q_{2jt}^* \tag{4.36}
\]
Chapter 4. Rent Capture Methods Reviewed

Differentiating (4.27) and (4.28) with respect to the charge rate

\[
\frac{\partial q_{1kt}}{\partial \rho} = -\frac{\xi_1^2(TAC)(\frac{\partial W_1}{\partial \rho})}{(X_1^2 \xi_1^2 + \frac{Y_1^2 d_1}{d_2})^2} \tag{4.37}
\]

\[
\frac{\partial q_{2jt}}{\partial \rho} = -\frac{\xi_2^2(TAC)(\frac{\partial W_2}{\partial \rho})}{(X_2^2 \xi_2^2 + \frac{Y_2^2 d_2}{d_1})^2} \tag{4.38}
\]

where

\[
\frac{\partial W_1}{\partial \rho} = \frac{Y \xi_1^2[(\beta_2 \xi_2^2 - \beta_1 \xi_1^2)4C(1-\rho)^2 \sigma_p^2 \beta^2]}{d_2} \tag{4.39}
\]

\[
\frac{\partial W_2}{\partial \rho} = \frac{X \xi_2^2[(\beta_1 \xi_1^2 - \beta_2 \xi_2^2)4C(1-\rho)^2 \sigma_p^2 \beta^2]}{d_1} \tag{4.40}
\]

It follows immediately that if \(\beta_1 \xi_1^2 = \beta_2 \xi_2^2\) then

\[
\frac{\partial q_{1kt}}{\partial \rho} = \frac{\partial q_{2jt}}{\partial \rho} = 0 \tag{4.41}
\]

If \(\beta_1 \xi_1^2 > \beta_2 \xi_2^2\) then

\[
\frac{\partial q_{1kt}}{\partial \rho} > 0 > \frac{\partial q_{2jt}}{\partial \rho} \tag{4.42}
\]

If \(\beta_1 \xi_1^2 < \beta_2 \xi_2^2\) then

\[
\frac{\partial q_{1kt}}{\partial \rho} < 0 < \frac{\partial q_{2jt}}{\partial \rho} \tag{4.43}
\]

Given that the expected rent is strictly concave in the quota allocation (see proposition 3.2) then the quota demands given by (4.29-4.30) provide a unique global maximum. From (4.31-4.32), it follows that the quota equilibrium with rent capture and uncertainty is identical to that with no uncertainty and no rent capture provided that (4.26) holds with equality. From (4.41), this equilibrium is unchanging with respect to the charge rate provided that the quota price is positive. If (4.26) does not hold with equality then from (4.33-4.36) the equilibrium with uncertainty and rent capture will yield a lower rent than the maximum. Combining the results from
(4.33-4.36) and (4.42-4.43), it follows that increasing the charge rate will increase the expected rent in the fishery □

Using the same approach as in proposition 4.7, identical results can be derived for an *ad valorem* royalty. Proposition 4.7 is proved for the specific fishery but it has general implications for ITQ fisheries. Provided that the short-run rent is strictly concave with respect to the quota allocation it can be shown from proposition 3.2 that under specific conditions the quota equilibrium without uncertainty is a unique global maximum. Proposition 4.7, therefore, leads to an interesting and important conclusion. If the resource owner is concerned solely with maximising expected rents and the uncertainty is with respect to the output price, increasing the charge rate of an *ad valorem* royalty or profit and net cash flow charge may actually increase the expected rents in the fishery. This result comes directly from the fact that certain types of rent capture can reduce the uncertainty faced by fishers. In reducing the level of uncertainty, the quota equilibrium approaches the quota allocation that maximises the expected short-run rent in the fishery for the given number of fishers and TAC. The cost of increasing the expected rents in the fishery with a higher charge rate, however, is to reduce the expected economic profit of fishers.

Another issue in comparing the methods of rent capture is their affect on fishers' incentives for innovation. Under a quota rental charge, *ad valorem* royalty or auction the benefits of individual innovation accrue directly to the quota-holder. Because the fisher pays a rental based only upon the market price of quota multiplied by quota-holdings, any extra returns that arise from individual risk taking or innovation are kept by the fisher. In contrast, with a profit charge or net cash flow charge the benefits of innovation are shared with the resource owner. If one accepts the Schumpeterian notion of intra-marginal rents\(^5\) as being both a payment and incentive for innovation

\(^5\)Schumpeter (1950) discusses this notion in detail.
then a quota rental charge, *ad valorem* royalty or auction may be preferred methods of rent capture. In a dynamic sense, therefore, by providing greater incentive for fisher innovation such methods of rent capture may stimulate more innovation and may give rise to greater rents from the fishery in the long run.

In assessing the effects of efficiency of the different methods of rent capture, it would seem that a lump sum fee and a quota transfer charge are the least desirable choices. These two methods are both capable of changing the Pareto efficient allocation even with no uncertainty. In comparison, a quota rental charge, *ad valorem* royalty, and profit and net cash flow charge will not change the quota equilibrium provided that no more than the annual value of quota-holdings is collected from the fishery. A quota rental charge, *ad valorem* royalty, and auction have the added advantage that they can allow fishers to capture the full benefits of innovation. In the case of uncertainty, a quota rental charge will also leave the quota equilibrium unchanged irrespective of the charge rate provided that the quota price is known with certainty. This is also true of an *ad valorem* royalty if the uncertainty facing fishers is not with respect to the output price. In the case of output price uncertainty, a profit charge, net cash flow charge, and an *ad valorem* royalty will change the quota equilibrium that maximises the expected rent less risk costs. Increasing the charge rate for all three rent capture methods will reduce the uncertainty with respect to fluctuations in the output price and in general will bring about an equilibrium with higher total expected rents.

### 4.12 Costs of Rent Capture

The costs of rent collection are likely to depend upon various characteristics of a fishery including the magnitude of the rent to be collected, the number of fishers and
their catches, the authority vested in the resource owner, and the human resources available to the resource owner. In certain fisheries, rent collection costs may prove to be a substantial proportion of the total rent captured and hence are important in determining the choice of a particular method of rent capture.

Determining the collection costs of different methods of rent capture requires intimate knowledge of the fishery where it is to be imposed. In a world where the profit and economic profit of each fisher is costlessly and perfectly known, there would be little difference in the collection costs across the different methods. The resource owner could simply determine an appropriate charge for each fisher with due consideration for the risk costs of fishers and collection costs. Unfortunately, such information is rarely if ever available to the resource owner and the choice of the method of rent capture is as much a reflection of the information constraints facing the regulator as the costs of rent collection and the effect upon efficiency, equity, and risk costs in the fishery.

One approach to compare different methods of rent capture is to contrast the information required for each and the fixed and variable costs associated with rent capture. In this sense, an auction of the quota imposes up-front costs on the resource owner that bears little relation to the size or the rent available from the fishery. These up-front costs may be considered a fixed cost of rent collection. Other methods of rent capture including a quota rental charge, *ad valorem* royalty, profit charge, and net cash flow charge would require ongoing expenditures to function effectively. These on-going costs may be considered as variable collection costs and could be a function of the number of fishers obliged to pay the rental and in the case of a royalty or quota rental charge the quantity harvested per fisher.

For a resource owner choosing an optimal TAC for a fishery, the variable collection costs of rent capture are an important consideration. In the choices available to
the resource owner, a method of rent capture that is a function of the total quantity harvested may reduce the optimal TAC if the resource owner wishes to maximise the rent in the fishery less the costs of rent capture. More generally, however, the TAC in fisheries is determined by biological factors and historical factors. In most fisheries, therefore, the issue with respect to collection costs is to minimise the expenses in capturing rent for a given TAC. The method(s) of rent capture that minimise collection costs, however, need not necessarily be the most desired method of rent capture. For example, the collection costs associated with a lump sum fee may be relatively small but such a method of rent capture may change the Pareto efficient quota equilibrium. In addition, some methods of rent capture such as a profit charge, net cash flow charge, and ad valorem royalty that may have higher rent collection costs may reduce the risk costs of fishers.

In comparing the different methods of rent capture, it may be noted that only an auction of the quota in perpetuity does not impose on going costs of rent collection on the resource owner. The bidding process itself reveals the total expected rent in the fishery less risk costs as well as providing a ready means of collecting the rent. There is essentially, therefore, no information burden imposed upon the resource owner and little or no enforcement costs required to determine any fraud in terms of the rental payments. A quota transfer charge shares this feature with an auction in that it too does not require information on the total rent, resource rent or individual earnings of fishers to collect rent for the resource owner. Unfortunately, a quota transfer charge creates an incentive for sellers of quota to misrecord their sale price so as to reduce the rental paid. To be an effective method of rent capture, therefore, it may be necessary to have a method for verifying the price at which quota traded. Such verification could only be achieved at additional cost to the resource owner.

Another method of rent capture that may have relatively small collection costs is
a quota rental charge. If the resource owner wishes to capture an amount equal to or less than the annual value of quota-holdings, the appropriate charge would be to set the quota rental as some percentage of the quota price multiplied by some defined rate of interest. The informational requirement would include, therefore, an estimate of the market price of quota and the quota-holdings of fishers. The quota price should, however, be readily available in a competitive quota market and the quota-holdings of fishers should be known to the resource owner in a well functioning ITQ fishery. A particular advantage of a quota rental charge is the relatively small informational burden it imposes on the resource owner. Changes in the value of the resource rent in the fishery should be reflected in the quota price and hence in the amount of rent captured. A quota rental charge would also require little policing or enforcement to ensure that the appropriate rental was paid by each fisher as the rental would be based on the quota-holdings of fishers.

An advantage of a lump sum charge is that it does not require an estimate of the profits of individual fishers to capture rent from the fishery. Provided there exists an estimate of the total profit in the fishery, a uniform lump sum charge is set equal to the desired rent to be captured divided by the number of quota-holders. This amount would then simply be charged to each of the fishers. Because the individual quota-holders would be known to the resource owner, the lump sum fee would provide no opportunity for tax evasion. Consequently, no costs would be incurred in policing fishers so as to prevent tax fraud. A draw-back with a lump sum fee is that it would require regular updating to ensure that an amount no more than a desired share of the resource rent was captured from the fishery. Another consideration with the lump sum fee is that it may leave certain fishers with after-tax losses even when capturing an amount no more than the estimated resource rent. If a resource owner wishes to avoid such a potentially distorting outcome then an estimate of the after-tax profits
of fishers would also be required. In this, a trade-off between reducing the risk of imposing distortions in the fishery would have to be balanced against the extra costs of obtaining individual financial information from fishers.

An *ad valorem* royalty shares a common feature with a quota rental charge and lump sum fee in that it does not require data on the individual profits of fishers. It would, however, require information on the landed price of fish, quota-holdings of fishers, and the rent in the fishery. Where the value of landings are already recorded by the resource owner, as is the case in most of Canada's fisheries, such information could be obtained at very little extra cost. A problem may arise, however, in obtaining an accurate landed price per fisher if the rental paid was based on the value of landings. Fishers may find it in their interest to reduce the recorded landed values so as to reduce their rental payments. To address this difficulty, a system of policing or verification of the landings may be required at an additional cost. To the extent that changes in the value of the rent are brought about by changes in the price of fish then an *ad valorem* royalty would be a flexible method of rent capture. Where changes in the rent are brought about by changes in the biomass or costs, some updating of the estimate of the rent in the fishery would also be required.

Both a profit charge and net cash flow charge share the feature that they require individual costs and earnings information from fishers to be made operational. Such information is likely to be much more costly to obtain and verify than a general estimate of the rent in the fishery. For this reason, both the net cash flow and profit charge are likely to cost more than the other methods of rent capture in collecting an equivalent amount of rent. Because of the incentive to inflate costs or reduce revenues so as to reduce the rental payable, a system of checking or verifying the profit or cash flow statements would also be required. In fisheries with a large number of vessels harvesting multiple species this may prove to be a considerable cost burden to the
resource owner.

Ranking the various rent capture schemes according to their costs of collection, it would seem that an auction would be the least costly method while a profit charge and net cash flow charge may prove the most burdensome. The collection costs for a quota transfer charge and lump sum fee may also prove to be less than a quota rental charge or *ad valorem* royalty which should impose similar costs on the resource owner.

### 4.13 Risk Sharing and Flexibility

The issue of risk sharing between the resource owner and fishers is important if one accepts the notion that fishers are risk averse. In the case where the resource owner is risk neutral and fishers are risk averse there may be a benefit to both parties from the sharing of risk. The same characteristics that allow for risk sharing between the resource owner and fishers, however, also make a method of rent capture more responsive to fluctuations in the value of the rent. For example, a rent capture scheme at a given charge rate that reduces the fluctuations and the risk costs of fishers will also adjust to changes in the rent brought about by such fluctuations.

In the case of a profit charge and uncertainty with respect to the output price, the risk cost of a fisher before and after rent capture may be determined in the same manner as (3.8). Assuming positive economic profits in every period, the risk cost of a fisher \( i \) before rent capture is \( \beta_i q_i^2 \sigma_P^2 \) while with rent capture the risk cost is reduced to \( \beta_i q_i^2 (1 - \rho)^2 \sigma_P^2 \). Similarly, *ceteris paribus*, in periods where \( P > \mathbb{E}\{P\} \), the rent captured by the resource owner will, therefore, be greater than in periods where \( P < \mathbb{E}\{P\} \). A profit charge is, therefore, able to reduce the risk cost of fishers and is a flexible method of rent capture. This feature of flexibility and risk sharing
is shared with a net cash flow charge with uncertainty with respect to the output and input prices. In the case of a net cash flow charge, however, the reduction in the risk cost in any period is complicated by the fact that risk may not only be shared within a time period but that negative cash flows can be capitalised and subtracted from future positive cash flows. Assuming fishers always have positive net cash flows, irrespective of the fluctuation in the output price, the risk cost faced by a fisher \( i \) is given by \( \beta_i q_i^2(1 - \tau)^2 \sigma_p^2 \). The risk premium is also reduced over what it would be without rent capture with a net cash flow charge when fishers incur both positive and negative net cash flows.

An ad valorem royalty is also shown to reduce the risk costs of fishers but only if there is uncertainty with respect to the output price. It differs from the profit and net cash flow charge, therefore, in that it does not reduce the risk costs of fishers due to uncertainty with respect to input prices. Assuming uncertainty only with respect to the output price, the risk cost of fisher \( i \) after imposing an ad valorem royalty is given by \( \beta_i q_i^2(1 - \tau)^2 \sigma_p^2 \). Although an ad valorem royalty does reduce the risk cost of fishers when there are fluctuations in the output price it does have the feature of collecting rent from fishers when they face losses. Where fishers view a marginal increase in losses as less desirable than a marginal decrease when profits are positive, it may be desirable to have a tiered royalty. In a tiered ad valorem royalty, the resource owner would set a floor and ceiling price. Whenever the output price was below the floor price no rental would be paid by fishers, in between the ceiling and floor price a fixed royalty rate would apply, and above the ceiling price a higher royalty rate would apply. The tiered ad valorem royalty would have the effect, therefore, of reducing the probability of capturing rent when fishers face temporary losses due to a low output price. Conversely, it would capture more rent when the output price was particularly high.
The quota price in an ITQ fishery where there is uncertainty only with respect to the output price is shown to be function of the expected output price, the variance of the output price, and other variables. For a given variance of the output price and provided that the quota price is known with certainty, a quota rental charge will not change the variance of the economic profit of fishers. As a result, it is unable to reduce the risk costs of fishers. If the quota price varies with changes in fishers' expectations of the input and output prices and biomass, however, it will be a flexible method of rent capture. This is because as the quota price changes with changed expectations in the fishery so too will the rent captured for a given charge rate.

A lump sum fee and auction are shown to leave fishers with the same risk costs with or without rent capture. In the case of the lump sum fee, subtracting a constant term or the rental paid to the resource owner, will leave unchanged the variance of the economic profits of fishers. In an auction, the risk faced by fishers is dependent upon the uncertainty with respect to the output and input prices and the TAC. Provided that the bid and auction process leaves unchanged the variance of the economic profits then an auction will also leave unchanged the risk costs faced by fishers.

A feature of a lump sum fee shared with a quota rental charge and *ad valorem* royalty is that it requires that a rental be paid each period by each fisher whether or not fishers incur a profit or loss. If it is the case that a dollar increase in losses is viewed as less desirable than a dollar decrease when profits are positive, such methods of rent capture may place an extra burden of risk on fishers. Such is not the case with a profit charge or net cash flow charge.

In summary, it would seem that a profit and net cash flow charge are the most capable of reducing the risk costs of fishers while a lump sum fee, auction, and quota transfer charge do so the least. An *ad valorem* royalty is shown to reduce the risk costs of fishers provided that there is uncertainty with respect to the output price.
Imposition of a tiered *ad valorem* royalty may also be advantageous where fishers view a marginal increase in losses as less desirable than a marginal decrease when profits are positive. A quota rental charge is not found to reduce the risk costs of fishers but is a flexible method of rent capture in that changes in the expected output and input prices, biomass, and level of uncertainty will be reflected in the rental paid.

4.14 Overview

An important question addressed in the thesis is how rent capture may affect the total rent in the fishery. It has been shown that a lump sum fee that collects no more than the annual value of quota-holdings may change the Pareto efficient allocation of quota. A quota transfer charge is found to alter the efficient quota equilibrium at any positive charge rate. A profit charge, net cash flow charge, *ad valorem* royalty, and quota rental charge do not change the quota equilibrium given no uncertainty or risk neutrality by fishers. Given uncertainty with respect to the output price, changes in the charge rate of an *ad valorem* royalty will, in general, change the quota equilibrium that maximises the expected rents less the risk costs of fishers. In this case, increasing the charge rate has the effect of reducing the risk costs of fishers and may move the quota equilibrium closer to the rent maximising quota allocation at the cost of reducing the expected utility of fishers. Changes in the charge rate of a profit charge and net cash flow charge will also, in general, change the quota equilibrium given uncertainty and risk aversion. As with the *ad valorem* royalty, increasing the charge rate can move the quota equilibrium closer to the allocation that maximises the expected rents in the fishery. A quota rental charge, however, will not alter the quota equilibrium with or without output price uncertainty provided that the quota price is known with certainty.
Another issue with respect to efficiency is the effects that rent capture may have upon the incentives for innovation in the fishery. A net cash flow charge and a profit charge imposed at high rates reduce the benefit for individual innovation by sharing any future intra-marginal rents with the resource owner. A quota transfer charge and quota rental charge do allow an individual to recover the full benefits of innovation that is not reflected in the quota price. An auction, *ad valorem* royalty, and lump sum fee allow fishers to fully recoup such benefits without reservation.

An important concern to a resource owner is the differential effects of rent capture on different fishers. It is shown that those fishers who earn a higher average profit on the fish harvested will prefer a quota rental charge over a profit charge that collects the same amount of rent. To the extent that net cash flow earnings per quota unit are a reflection of intra-marginal rents in the fishery, it is shown that highliners will also prefer a quota rental charge over a net cash flow charge. A lump sum fee is favoured in terms of annual economic profits over a profit charge or quota rental charge by those fishers who earn higher than average profits or have higher than average quota-holdings. An *ad valorem* royalty is shown to be equivalent to a quota rental charge if fishers face the same output price and the rental is assessed on the quota-holdings of fishers. A quota transfer charge imposes burdens only upon those fishers selling or leasing quota.

The different methods of rent capture also differ with respect to the costs of collection. It is suggested that an auction may be the most cost effective method of collecting rent from the fishery. Those methods of rent capture not requiring individual costs and earnings information from fishers including a lump sum fee, quota rental charge, *ad valorem* royalty, and quota transfer charge may also be cost effective methods of rent collection. A net cash flow charge and profit charge that do require individual data from fishers along with a system for verifying returns are
likely to be the more expensive methods of rent collection.

Another distinguishing feature among the rent capture methods is their ability to reduce the risk costs of fishers. It is shown that a lump sum fee, auction, and quota transfer charge do not reduce the risk costs faced by fishers. A profit charge and net cash flow charge do reduce risk costs if the uncertainty faced by fishers is with respect to the output and input prices. An *ad valorem* royalty is also capable of reducing the risk costs of fishers provided a source of uncertainty is with respect to the output price. A profit, net cash flow charge, and an *ad valorem* royalty are shown to have some flexibility to adjust the rent captured with the actual rent in the fishery.

One other important factor to consider in choosing any method of rent capture is the ability to implement any given rent capture scheme in a fishery. The ability to implement a given method of rent capture is governed by a number of factors including the management skills and resources available to the resource owner, traditional and historical fishing rights, the spatial size and number of fishers in the fishery, and the expected value of the rent to be collected. For instance, a profit charge may be a desirable method of rent capture with a relatively small number of fishers but may prove too burdensome in terms of a collection costs in a much larger fishery. Similarly, an auction and a quota rental charge may not be possible in a small fishery where there may not be a competitive bidding process or competitive quota trading but may function well in a fishery where there are a large number of fishers.

In implementing a rent capture scheme, traditional fishing rights or access is also an important consideration. Where fishers have been given access to a fishery in the past, the introduction of ITQs and the auctioning of quota could lead to considerable protest from fishers. If such protest took the form of sabotaging gear of successful bidders, quota-busting, and poaching it could put at risk the potential benefits of ITQs. In many cases, therefore, it may be appropriate to allow for at least some
“grandfathering” in of quota on the basis of historical catches. This has certainly been the practice in countries such as New Zealand, Canada, Australia among others. If historical rights are recognised in the initial quota allocations by the resource owner then any method and rate of rent capture should be announced prior to any quota trading. If no such announcement is made and there is no expectation of rent capture then the resource owner faces the prospect of collecting resource rent from fishers who have already paid the expected resource rent to the previous quota-holders.
Table 4.1: Short-run profits of fishers with collection of 100% of the annual value of quota-holdings and given risk neutrality

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Profit</th>
<th>Rent Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>100% Quota Charge:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>124.80</td>
<td>38.40</td>
</tr>
<tr>
<td>F2</td>
<td>11.20</td>
<td>9.6</td>
</tr>
<tr>
<td>Total</td>
<td>408.00</td>
<td>144.00</td>
</tr>
<tr>
<td><strong>26.09% Profit Tax:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>120.63</td>
<td>42.57</td>
</tr>
<tr>
<td>F2</td>
<td>15.37</td>
<td>5.43</td>
</tr>
<tr>
<td>Total</td>
<td>408.00</td>
<td>144.00</td>
</tr>
<tr>
<td><strong>15.79% Net Cash Flow Charge:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>124.80</td>
<td>38.40</td>
</tr>
<tr>
<td>F2</td>
<td>11.20</td>
<td>9.60</td>
</tr>
<tr>
<td>Total</td>
<td>408.00</td>
<td>144.00</td>
</tr>
<tr>
<td><strong>8.57% Ad Valorem Royalty:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>124.80</td>
<td>38.40</td>
</tr>
<tr>
<td>F2</td>
<td>11.20</td>
<td>9.60</td>
</tr>
<tr>
<td>Total</td>
<td>408.00</td>
<td>144.00</td>
</tr>
<tr>
<td><strong>Lump Sum Fee:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>139.20</td>
<td>24.00</td>
</tr>
<tr>
<td>F2</td>
<td>-3.20</td>
<td>24.00</td>
</tr>
<tr>
<td>Total</td>
<td>408.00</td>
<td>144.00</td>
</tr>
</tbody>
</table>
Table 4.2: Short-run profits of fishers with collection of 50% of the annual value of quota-holdings and given risk neutrality

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Profit</th>
<th>Rent Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>50% Quota Charge:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>144.00</td>
<td>19.20</td>
</tr>
<tr>
<td>F2</td>
<td>16.00</td>
<td>4.80</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>480.00</td>
<td>72.00</td>
</tr>
<tr>
<td><strong>13.04% Profit Tax:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>141.91</td>
<td>21.29</td>
</tr>
<tr>
<td>F2</td>
<td>18.09</td>
<td>2.71</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>480.00</td>
<td>72.00</td>
</tr>
<tr>
<td><strong>7.89% Net Cash Flow Charge:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>144.00</td>
<td>19.20</td>
</tr>
<tr>
<td>F2</td>
<td>16.00</td>
<td>4.80</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>480.00</td>
<td>72.00</td>
</tr>
<tr>
<td><strong>4.29% Ad Valorem Royalty:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>144.00</td>
<td>19.20</td>
</tr>
<tr>
<td>F2</td>
<td>16.00</td>
<td>4.80</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>480.00</td>
<td>72.00</td>
</tr>
<tr>
<td><strong>Lump Sum Fee:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>151.20</td>
<td>12.00</td>
</tr>
<tr>
<td>F2</td>
<td>8.80</td>
<td>12.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>480.00</td>
<td>72.00</td>
</tr>
</tbody>
</table>
Table 4.3: Cost/return from quota trading assuming rent capture of 50% of the annual value of quota-holdings and risk neutrality

<table>
<thead>
<tr>
<th>Rent Capture Method</th>
<th>Cost/Return Quota Trades</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>50% Quota Charge:</strong></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>-72.0</td>
</tr>
<tr>
<td>F2</td>
<td>72.0</td>
</tr>
<tr>
<td><strong>13.04% Profit Charge:</strong></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>-125.2</td>
</tr>
<tr>
<td>F2</td>
<td>125.2</td>
</tr>
<tr>
<td><strong>7.89% Net Cash Flow Charge:</strong></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>-132.6</td>
</tr>
<tr>
<td>F2</td>
<td>132.6</td>
</tr>
<tr>
<td><strong>4.29% Ad Valorem Royalty:</strong></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>-72.0</td>
</tr>
<tr>
<td>F2</td>
<td>72.0</td>
</tr>
<tr>
<td><strong>Lump Sum fee of 12 units/fisher:</strong></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>-144.0</td>
</tr>
<tr>
<td>F2</td>
<td>144.0</td>
</tr>
</tbody>
</table>
Table 4.4: Short-run quota equilibrium before and after a lump fee charge is imposed on the fishery that collects an amount equal to 100% of the annual value of quota-holdings.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Profit</th>
<th>Rental Paid</th>
<th>Quota-Holdings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Rent Capture:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>163.20</td>
<td>0</td>
<td>224</td>
</tr>
<tr>
<td>F2</td>
<td>20.80</td>
<td>0</td>
<td>56</td>
</tr>
<tr>
<td>Total</td>
<td>552.00</td>
<td>0</td>
<td>840</td>
</tr>
<tr>
<td>Lump Sum Fee:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>165</td>
<td>48</td>
<td>245</td>
</tr>
<tr>
<td>F2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>495.00</td>
<td>144</td>
<td>735</td>
</tr>
</tbody>
</table>
Table 4.5: Short-run quota equilibrium before and after a 100% quota transfer charge is imposed on the fishery

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Profit</th>
<th>Quota-Holdings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Rent Capture:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>163.20</td>
<td>224</td>
</tr>
<tr>
<td>F2</td>
<td>20.80</td>
<td>56</td>
</tr>
<tr>
<td>Total</td>
<td>552.00</td>
<td>840</td>
</tr>
<tr>
<td>100% Quota Transfer Charge:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1</td>
<td>162.19</td>
<td>218.75</td>
</tr>
<tr>
<td>F2</td>
<td>21.25</td>
<td>61.25</td>
</tr>
<tr>
<td>Total</td>
<td>550.32</td>
<td>840</td>
</tr>
</tbody>
</table>
Chapter 5

Rent and the BC Sablefish Fishery

It will appear, I hope, that most of the problems associated with the words “conservation” or “depletion” or “overexploitation” in the fishery are, in reality, manifestations of the fact that the natural resources of the sea yield no economic rent.


5.1 Introduction

The problem addressed in a theoretical framework in chapters 3 and 4 is examined empirically with reference to the BC sablefish fishery. Prior to comparing different methods of rent capture in the fishery, it is necessary to have an estimate of the rent that accrues to the individual vessels. This chapter uses several approaches for estimating the rent before and after the introduction of ITQs into the fishery. These estimates are used in chapter 6 to simulate the effects of rent capture in the fishery.

Empirical estimates of the rent in fisheries are common in the resources literature. One of the best known works is by Crutchfield and Pontecorvo (1969) who estimated the potential rent in the Alaska Bristol Bay and Washington Puget Sound salmon fisheries. Flagg (1977), using a Schaefer model of fishery exploitation examined the difference between a maximum sustainable yield (MSY) and maximum
economic yield (MEY) in the eastern tropical Pacific tuna fishery. More recently, Devoretz and Schwindt (1984) have examined the rent that may be collected from some of Canada's Pacific fisheries. Using the Royal Commission on Pacific Fisheries Policy (1982) as a starting point, they analyse the returns from a royalty per ton on the quantity harvested and an auction of commercial fishing licences by the Government of Canada in the salmon and roe herring fisheries. The traded value of commercial fishing licences has also been used by Schwindt (1986) to estimate the rent in the BC salmon industry. Using the licence values as a proxy of the capitalised rent in the fishery, Schwindt (1986) applies several different discount rates to obtain an estimate of an average annual rent.

More recent empirical studies by Dupont (1988, 1990) and Squires (1984, 1987) have attempted to measure the rent in fisheries through the use of restricted profit functions. Both these approaches use duality theory to address regulatory problems in fisheries. In particular, Squires uses a restricted translog profit function to show that regulations may be improved by regulating several inputs in multi-species fisheries. In this manner, inefficient product and factor proportions may be avoided allowing the total rent in the fishery to increase. Dupont (1988, 1990) uses a normalised quadratic restricted profit function to estimate the effects of rent dissipation in a restricted access fishery. The profit function is then used to estimate the costs of rent dissipation from input substitution, fleet redundancy, and fleet composition.

The general thrust of these studies has been to examine the issue of rent dissipation and the effects of inappropriate regulation in fisheries. Only with the introduction of rights based management in the past decade has the issue of estimating the rent in a fishery with a view to rent capture become an issue. One of the first studies to examine the question of rents with ITQ management was by Geen and Nayar (1989) in reference to the Australian southern bluefin fishery. Using a model developed
specifically for the fishery they investigate the total rent with free entry and with ITQ management. They find that economic rents of $A 10 million/year can be earned by fishers owning quota rights. In a study using New Zealand data, Lindner et al. (1989) compare traded quota prices to estimates of profitability in the industry using aggregate industry revenues, costs, and asset values. On the basis of the industry study, they conclude that in aggregate the fishing industry was incurring losses in 1987/88 while expectations of future profits were positive as reflected by positive quota prices.

The focus of chapter 5 is to present estimates of the rent in the BC sablefish fishery in two periods; 1988 when only restrictive licensing was in place, and in 1990 when individual quota management was first introduced into the fishery. Three approaches are employed to estimate the rent in the fishery. All approaches make extensive use of a Canadian Department of Fisheries and Oceans' (DFO) 1988 costs and earnings survey (CES). In a direct approach to estimating the resource rent in the fishery, the profits of fishers are obtained directly from the 1988 CES under suitable assumptions with respect to the allocation of implicit and indirect costs among species. In a second approach, the market values of sablefish licences in 1988 are used to estimate the expected annualised resource rent in the fishery. In another approach, two profit functions are estimated using 1988 data. Estimates of individual profits for 1988 are then obtained directly from the estimated functions. Using updated prices for 1990, the profit functions are used to predict the profits of fishers in 1990. These predicted profits are then compared to estimates calculated using the price of quota traded in an open market and the remuneration system employed in the sablefish fleet for paying the crew and the vessel owner.
5.2 Description of The Fishery and Data Sources

5.2.1 Background

The fishery chosen for the study of rent capture issues is the BC sablefish fishery. This resource generated a gross landed value of some $CDN 18 million in 1990 and has been managed with limited entry licensing since 1981. This licensing system restricted the use of gear by fishers and the total number of licence-holders to 48. Under a management system that existed until the end of 1989 fishers faced a restricted fishing season for sablefish. In 1988, all fishers were restricted to a 20 day fishing season which the fishers could choose themselves out of a possible seven choices determined by the Canadian Department of Fisheries and Oceans (DFO) in consultation with the fishers. By comparison, the fishing season in 1981 with a similar TAC was 245 days. In early 1990, individual vessel quotas (IVQs) were introduced into the fishery with support of the industry for a two year trial period. This trial period was subsequently extended until the end of 1992. The IVQs were assigned gratis to fishers on the basis of past catches and vessel length, denominated as a proportion of the total allowable catch, and made transferable only among licence-holders for amounts no less than the initial quota allocations [Canada Department of Fisheries and Oceans (1990b)].

A general feature of the sablefish fishery is that it has had a relatively stable biomass and total allowable catch [Saunders and McFarlane (1990)]. Almost the entire catch is exported to Japan [Longva (1990)]. Harvesting the resource are two types of vessels employing different gear. A trap or pot harvesting method is generally employed by larger vessels and involves the setting of baited traps at depths of 250-600 metres. These traps, attached to each other and buoys at the surface, are generally left to "soak" for 12 to 24 hours before recovery. An alternative method of fishing is to use bottom longline gear in which baited hooks lie on or near the sea bottom.
and are maintained in position by anchors attached to buoys at the surface. Longline gear is generally left to soak for approximately 1 and a half to three hours prior to recovery by fishers. Because of the depth at which the gear-types are often used both longline and traps are capable of being highly selective for targeting sablefish.

In the first year of IVQ management in 1990, there were 15 trap and 15 longline vessels operating in the fishery. The trap vessels accounted for 75% of the total harvest of 4,260 MT while the longline vessels caught the remainder. In contrast, in 1988 with total landings of some 4,600 MT there were some 21 trap and 25 longline vessels actively operating in the fishery. Many of these fishers also operated in other fisheries such as halibut and salmon.

5.2.2 Data Sources

The different approaches to estimating the rent in the BC sablefish fishery make extensive use of a DFO costs and earnings survey for 1988 and/or DFO catch statistics data. In the survey, 17 longline fishers and 11 trap fishers were interviewed including some of the smallest and largest vessels in the sablefish fleet. The survey obtained information on fishing revenue and direct fishing costs per species, financial payments, repairs and maintenance, and the value of assets employed by fishers. In addition to the costs and earnings survey, data was obtained on marine fuel prices from Chevron Canada, catch statistics by species per vessel from DFO, and the tonnage of vessels from the Vancouver ship registry. Summary statistics from the survey and other sources are presented in Table 5.1. The table provides minimum, maximum, mean, and the coefficient of variation of various variables including the estimated profits of fishers, landings of sablefish and other species, vessel size, sablefish revenue and direct and indirect expenses of fishers.
5.3 Direct Approach

Using the CES data, a direct measure of the profit of vessels may be obtained for 1988. Total sablefish profits are calculated as the total sablefish revenue per vessel less direct fishing costs attributable to sablefish such as fuel and labour and less a portion of indirect and implicit fishing costs. Total vessel profits are calculated in a similar manner by subtracting from total revenue of vessels the total direct fishing expenses and total indirect and implicit fishing costs. The indirect and implicit costs attributable to sablefish fishing include a portion of the opportunity cost for the assets employed by the vessel, a share of the total vessel depreciation, and a portion of the opportunity cost wage for the skipper in owner operated vessels.

The factor used for apportioning overhead to sablefish and other species for each vessel equalled the ratio of direct fishing expenses from sablefish alone to total direct fishing expenses. This ratio averaged 56% over the complete sample and varied from 21% to a 100% for individual vessels. For vessels where the ratio was less than 100% its value was increased by 10, 20, and 30%, where applicable, to assess its sensitivity on the estimated profits of fishers. This had the effect of reducing the mean sablefish profit of vessels by 4, 9, and 13%.

The direct fishing costs per species were obtained directly from the CES. In the survey instrument, fishers were asked to provide their total income from various fisheries along with labour costs, fuel, bait and other expenses. Separating sablefish revenue from other species and subtracting the direct expenses associated with sablefish provided a measure of the variable sablefish profits per vessel. To obtain an estimate of the sablefish profits, an implicit cost or an opportunity cost wage for the skipper was determined for all those vessels where the captain was the owner operator. This opportunity cost wage on an annual basis was calculated using an
estimate of the average weekly earnings of fishers using a methodology described in Appendix B. Where applicable, this opportunity cost wage and the total depreciation on vessel and gear as given in the CES were multiplied by the ratio used for allocating overhead to sablefish and subtracted from sablefish revenue. In addition, a measure of the opportunity cost of the assets employed per vessel was obtained by using the fishers' own estimate of the assets employed including the value of the vessel and gear. This estimated value was obtained by asking fishers what price they would expect for their vessel if they sold it that day and the value of their nets and gears as the first of January, 1988. acquisitions less losses-sales. The estimated value of assets was then multiplied by an interest rate equal to 11.83%, or the mean prime lending rate on business loans plus 1%, to obtain an annual cost per fisher. This annual cost of the assets employed was then multiplied by the ratio for allocating overhead to sablefish and subtracted from the estimated variable sablefish profits as per (5.1) to obtain a measure of the sablefish profits. This estimate of the sablefish profits uses data exclusively from the CES. An alternative measure for the indirect costs of fishers using second-hand vessel prices is provided in the profit function approach to estimating the rents in the fishery.

\[
\text{Sablefish Profit} = R_s - C_s - \kappa[Y + \Delta + rA] \tag{5.1}
\]

where: \( R_s \) is total revenue from sablefish, \( C_s \) is the direct fishing expense associated with sablefish, \( \kappa \) is the ratio for allocating indirect and implicit costs to sablefish, \( Y \) is the opportunity cost wage associated with the skipper in owner-operated vessels, \( \Delta \) is total depreciation associated with the vessel, \( r = 0.1183 \) is the mean prime business lending rate plus 1% for 1988, and \( A \) is the value of the assets employed by fishers.

The estimated sablefish profits for the vessels included in the CES by gear-type is
presented in Tables 5.1 and 5.2. Consulting Table 5.2, the mean sablefish profits for
longline and trap vessels respectively was some $79,000 and $211,000. These estimates
of the profits of fishers may, however, be biased downwards. This is because the value
of assets provided by fishers in the CES may overestimate their true value. For
example, the mean value of vessels from the CES is some $465,000 while comparable
second-hand values of vessels based on discussions with a fish boat trader (K.Gaynor,
pers. comm.) and advertisements in commercial fishing trade magazines for the
same period range in price from $50,000-$150,000. A possible explanation for the
discrepancy lies in the wording of the survey instrument. In particular, respondents
were asked to provide a market value of their vessels with fishing licences and then
later asked to separately list the value of these licences. Separating the value of
fishing licences from the value of a vessel when both are normally sold together may,
however, have posed problems for fishers.

Using the survey estimates of vessel and sablefish profits, a number of profitability
ratios may be constructed. These ratios are presented in Table 5.2 and are useful for
comparing relative profitability between gear-types and rates of return. Consulting
Table 5.2, trap vessels earned a mean profit of $1.20 per kilogram of sablefish landed
while longline vessels earned some $1.38/kg. Over all gear-types, the mean ratio of
before-tax sablefish profits to gross revenue from sablefish was some 35% while before
tax profits from all species to the value of equity employed was some 33%. Both these
measures exceed the target returns for healthy fleet performance in the BC salmon
fishery [DPA Group (1988), 43] of some 6% for before tax profit to gross income and
15% for before tax profit to equity. In both these ratios, the mean ratio for longline
vessels exceeded that of trap vessels. It suggests, therefore, that although trap vessels
had higher mean absolute profits than longline vessels they were not necessarily more
profitable in terms of the equity employed or sablefish landed.
Because the CES obtained data from only 28 of the 46 fishers actively fishing for sablefish, it is necessary to estimate the sablefish profits for the missing vessels to obtain a measure of the total sablefish profits in 1988. To provide such estimates data common to all vessels were employed. The data were obtained from DFO catch statistics and include the age of the vessel in years and the total value of sablefish landed for 1988. The estimates of sablefish profit for trap and longline vessels in the CES were then separately regressed on the independent variables of value of sablefish landings ($X_1$) and the age of vessel ($X_2$).

The estimated coefficients from these ordinary least squares regressions were then used to obtain a mean prediction of the sablefish profits for vessels not in the CES. The results of the regressions are given in equations (5.2) and (5.3).

**Trap Vessels**

\[ \hat{Y}_i = 0.3587X_1 - 374.82X_2 \]  
\[ (0.0677) \quad (1961.2) \]

\[ r^2 = 0.821 \quad df = 10 \quad F_{2,10} = 23.99 \]

**Longline Vessels**

\[ \hat{Y}_i = 0.4484X_1 - 694.02X_2 \]
\[ (0.0551) \quad (594.81) \]

\[ r^2 = 0.914 \quad df = 14 \quad F_{2,14} = 74.64 \]

where $r^2$ is the raw moment r-square, standard errors are in parentheses, * indicates coefficient is significantly different from zero at the 10% level of significance, $\hat{Y}_i$ is sablefish profit, $X_1$ is value of sablefish landed, and $X_2$ is age of vessel in years.
In equations (5.2) and (5.3) only the coefficients with respect to the value of sablefish landings were significantly different from zero. The calculated F statistics test whether collectively the coefficients are significantly different from zero. For both equations, the null hypothesis of zero coefficients is rejected at the 10% level of significance. Because both equations do not have a constant term, the standard \( r^2 \) value is not well defined. For this reason, the raw moment \( r^2 \), which measures the deviation in the actual and predicted dependent variable from zero is presented. The \( r^2 \) value for both equations is high considering the estimates are obtained from cross-sectional data. It should be emphasised, however, that the performance of an equation for forecasting or prediction is quite distinct from the classical \( t \), \( F \), and \( r^2 \) statistics. Good forecasts may come from regression models with low \( r^2 \) or one or more insignificant regression coefficients if there is relatively little variation in the dependent variable.

Using the estimated coefficients from (5.2) and (5.3) and the mean values of sablefish landings and age of vessels for the two gear-types, a mean prediction of sablefish profits was obtained. The predicted values and 95% confidence intervals for the 18 vessels not in the CES who caught sablefish in 1988 are presented in Table 5.3. Interestingly, the lower confidence interval for the mean prediction for trap vessels exceeds the upper confidence interval for the longline vessels. In both cases, the confidence intervals are in a positive range with the means for trap and longline vessels being respectively some $190,000 and $64,000. Multiplying the mean predicted sablefish profits by the number of vessels for each gear-type, an aggregate measure of the profits for those vessels not in the CES can be obtained. Summing this predicted aggregate value to the sum of the estimated profits of vessels in the CES, a measure of the total sablefish profits in the fishery can be determined. These values are presented in Table 5.4. Consulting Table 5.4, it would seem that the 1988 sablefish
profits in the fishery are estimated to be some $6.2 million. This provides an estimate of both the annual resource rent and the intra-marginal rents in the fishery. A lower range for the estimated sablefish profits can also be obtained by using the lower 95% confidence intervals given in Table 5.3. This provides a lower estimate of the total fishery profits of some $5.2 million.

5.4 Licence Values Approach

Another approach to estimating the profit of fishers in 1988 is to use their estimated value of sablefish licences. These licences, restricted to a total number of 48, are a prerequisite for being a legal participant in the fishery and are assigned to a particular individual and vessel. To the extent that newcomers are able to purchase vessels with sablefish licences from fishers retiring from the fishery, such licences command a positive price. These sablefish licences provide fishers with a legal fishing privilege and the price paid for a licence reflects the market's expectation of resource rents in the fishery less an allowance for risk under the management policies in place in 1988.

Employing a methodology used by Schwindt (1986) one may use the aggregate value of sablefish licences as a proxy of the expected capitalised rent in the fishery in 1988. Depending upon the level of risk aversion by fishers and the perceived uncertainty in the fishery, the expected capitalised rent in the fishery should be equal to or greater than the total value of sablefish licences. Estimates of the market price of sablefish licences is provided in the CES. In the survey instrument, fishers were asked to provide the price they would expect to receive if they sold their vessels with all licences and the specific price that would be paid for a sablefish licence. The prices provided by fishers is presented in Table 5.1. The mean price for a sablefish licence was some $280,000 while the range was from $100,000 to $600,000. To obtain an
estimate of the licence values for vessels not in the CES, a mean licence value per metre of vessel length of some $14,500/metre was calculated from the 26 vessels in the CES where data was available. This mean price was multiplied by the remaining number of licences in the fishery and added to the total from vessels in the CES to obtain a total value of the licences in the fishery of some $13.3 million. This sum represents the expected capitalised resource rent in the fishery less any discounting by fishers because of risk.

To obtain a measure of the annual expected resource rent from the fishery, the aggregate value of sablefish licences may then be multiplied by an appropriate rate of discount. Using a discount rate equal to one percent above the mean prime business lending rate for 1988 or 11.83% and multiplying the total value of licences by this amount, an estimate of the annual resource rent in the fishery less discounting because of risk is some $1.6 million. In calculating this annualised rent it is implicitly assumed that fishers face an infinite planning horizon. In actual fact, fishers may face a much shorter pay-back period or planning horizon. The shorter the planning period of fishers the greater must be the annual rent in the fishery. For example, using the same discount rate and assuming fishers have a pay-back period of five years and ten years, the annual resource rent in the fishery less an allowance for risk is, respectively, some $3.7 and $2.4 million. It should be emphasised, however, that estimates of the rent in the fishery using 1988 licence values reflect the expected resource rent for the period 1988 only. Information from a broker in the fishing industry [K. Gaynor, pers. comm.] in 1990 indicates that the value of sablefish licences with quota increased some three to four fold with the introduction of IVQs. Much of this increase in value is probably attributable to the coupling of licences with individual quotas which in turn give fishers a much more secure fishing privilege than licences alone. It is also possible that the profits in the fishery are higher today than in 1988. This may be
due to efficiency improvements due to IVQ regulations and an increase in the price of sablefish since 1988.

5.5 Profit Function and Other Approaches

The third approach to estimating the rent in the fishery is to predict individual profits per vessel using two restricted profit functions. Unlike the other approaches to estimating rent in the fishery, the estimated profit functions may also be used to predict the profits of fishers in 1990 using updated prices and data. The use of a profit function assumes that fishers seek to maximise profit by choice of an input and output mix. The approach is based upon duality theory [Diewert (1974)] in that the direct production function of a firm may be estimated from a dual profit function. The dual functions, in contrast to direct production functions, use input and output prices as arguments instead of quantities. The profit function can also provide estimates of the elasticities of substitution between inputs and outputs, elasticities of intensity between variable and restricted inputs, and returns to scale.

Choosing the functional form of the profit function to be estimated is governed by a number of issues. Theoretically, such a function should not impose a priori restrictions on the elasticities of substitution among inputs and outputs. The two functional forms used in this thesis, a normalised quadratic and a translog variable profit function, are both flexible in this property. Estimates of the unknown parameters of the profit functions are estimated using the CES, landing slip data, and market price information solicited by the researcher. In particular, the price and catch of sablefish and other species were obtained from landing slip data obtained from DFO, fuel prices from Chevron Canada, an opportunity cost wage was calculated using average weekly earnings and unemployment insurance payments from Statistics Canada. A detailed
description of the data used in estimation of the functions is provided in Appendix B.

One of the profit functions used in estimating sablefish profits is the normalised quadratic form. This functional form has the advantage that convexity, a necessary condition for profit-maximisation, can be imposed as required on the profit function with no loss in flexibility. The function was first defined by Fuss (1977) and later in a general form by Diewert and Ostentoe (1988) and more recently by Diewert and Wales (1988, 1990). A normalised quadratic profit function was first used in a fishery context by Dupont (1988, 1990) in a study of rent dissipation in the BC salmon fishery. Imposing linear homogeneity in prices, a variant of the function is defined by (5.4). The notation used to describe the profit function is defined as follows:1

\[ \Pi_f = \text{restricted profit.} \]
\[ \alpha \text{ is a prespecified parameter.} \]
\[ a_{ik}, i = 2 \ldots N \text{ and } k = 2 \ldots N \text{ are parameters to be estimated.} \]
\[ c_{iz}, c_i, \text{ and } d_i, i = 1 \ldots N \text{ are parameters to be estimated.} \]
\[ D \text{ is a dummy which is 1 for trap and 0 for longline vessels.} \]
\[ Z_1 \text{ is the restricted input of vessel size.} \]
\[ P_i, i = 1 \ldots N \text{ are input and output prices.} \]

\[
\Pi_f^R(P, Z_1) = \frac{1}{2} \alpha Z_1 \sum_{i=2}^{N} \sum_{k=2}^{N} a_{ik} (P_i P_k)/P_1 + \\
\sum_{i=1}^{N} c_{iz} P_i Z_1 + \sum_{i=1}^{N} c_i P_i + \sum_{i=1}^{N} d_i P_i D \tag{5.4}
\]

The function defined by (5.4) is a returns to scale flexible functional form [Diewert and Wales (1990)] and requires one less free parameter than a flexible functional form.

1An initial hypothesis is that the profit function defined by (5.4) assumes joint-in-inputs technology for sablefish and other species. This hypothesis may be subsequently tested econometrically.
Symmetry may be imposed on the unit profit or net revenue function defined by (5.4) by setting the coefficients $a_{ik} = a_{ki}$. With symmetry imposed there are $N(N-1)/2$ free parameters, $N c_1$ free parameters, $N c_i$ free parameters, and $N d_i$ free parameters. Following Diewert and Wales (1988) and Dupont (1988, 1990) an $a$ priori choice for the prespecified parameter $\alpha$ is $1/Z'$, where $Z'$ is the first observation of the restricted input.

In order for the unit profit function to describe the underlying production technology, it is necessary that (5.4) be linearly homogeneous and convex in prices, non-decreasing in the fixed factor, and monotonic in the output supply and input demand functions. Linear homogeneity is a maintained hypothesis with $P_1$, the price of labour services, being the normalising price.

Convexity in prices of the unit profit function is established globally and locally when the matrix defined by $A$ with individual parameters $a_{ik}$ is positive semidefinite. A sufficient condition for a positive semidefinite $A$ matrix is that all the eigenvalues be nonegative. Monotonicity can be verified by observing whether the predicted outputs are positive and the predicted inputs are negative.

Using Hotelling's lemma the associated net supply equations to (5.4) may be derived. For $i = 2, 3, 4$ with symmetry imposed the net supplies are given by equation (5.5).

$$X_i = \alpha Z_1 \sum_{k=2}^{N} a_{ik} (P_k / P_1) + c_{i1} Z_1 + c_i + d_i D$$

For $i = 1$ the net supply is given by equation (5.6).

$$X_1 = -\frac{1}{2} \alpha Z_1 \sum_{i=2}^{N} \sum_{k=2}^{N} a_{ik} (P_i P_k) / P_1^2 + c_{11} Z_1 + c_1 + d_1 D$$
The price of labour services \((P_1)\) is defined as the normalising price that assures homogeneity of degree zero in the outputs and inputs while the restricted input \((Z_1)\) is defined as the vessel length in metres. The net supplies include the input demands for labour \((X_1)\) and fuel \((X_2)\) and the output supplies of other species \((X_3)\) and sablefish \((X_4)\). The set of equations to be estimated include (5.5) and (5.6). By convention, inputs are defined as negative quantities and outputs as positive quantities.

The price of labour services \((P_1)\) was calculated as an expected average weekly earnings of fishers. This was necessary so as to avoid a possible simultaneity problem in estimation because in the fishing industry crew are often paid a specific share of the landed value of the harvest. For example, in the sablefish industry fishing crew are generally paid 50% of the landed value of fish after deducting operating expenses such as bait, fuel, and provisions. The methodology used to calculate an expected average weekly earning was the same as used by Dupont (1988, 1990) and involved weighting the mean wage for different regions of the BC coast by the probability of being employed. This labour price index was set such that the first observation was set equal to unity when estimating the normalised quadratic unit profit function. This procedure was followed for all prices and for the fixed factor. Dividing the labour price index into the total labour expenditures per vessel plus bait and food, an implicit aggregate index of labour quantity \((X_1)\) was obtained.

The price of fuel \((P_2)\) was obtained on a regional basis from Chevron Canada and adjusted by the fishing dates of the vessels in 1988. Dividing the fuel price index into the expenditures on fuel obtained from the CES, an implicit quantity index \((X_2)\) was derived. The price of other species \((P_3)\) was also obtained from DFO landing statistics. Specifically, an aggregate price index per vessel was obtained by constructing a Laspeyeres and Paasche index for each vessel relative to the mean price and total landings per species for all vessels in the sample. Taking a geometric
average of the two indexes, a Fisher price index [Diewert (1989)] per vessel for all species other than sablefish was obtained. This index was then divided into the total revenue from other species other than sablefish to obtain an implicit quantity index. The price of sablefish ($P_4$) was obtained directly from landing statistics routinely kept for all registered commercial fishing vessels in BC. The price measured in \$/kg was indexed and divided into the revenue per vessel obtained from the CES to derive an implicit quantity of sablefish ($X_4$).

Appending an additive disturbance term to each of the equations in (5.5) and (5.6), an estimate of the unknown parameters may be obtained. In estimation it was assumed that the disturbance vector is independently and identically distributed with mean vector zero and a constant, nonsingular covariance matrix. The disturbances are assumed to arise from errors in optimisation by fishers. In estimating the unit profit function, one observation was dropped from the sample. The vessel dropped from the sample only harvested sablefish and consequently no price variable was available for species other than sablefish.

Following estimation of the unknown parameters, the properties of the unit profit function may be examined. Because the eigenvalues of the $A$ matrix were not all nonnegative, the function was not found to be globally convex. A rejection of the convexity property implies that the input demands and output supplies may not be well-defined. As a result, it may be possible to alter a combination of outputs and inputs and increase the variable profit of a fisher. Convexity may be violated for a number of reasons. Wales (1977) has shown that estimates of a flexible functional form may violate convexity even if the data come from a well-behaved technology. Squires (1987) also notes that inconsistent aggregation in constructing the price and quantity variables may also contribute to the problem. Because of nonconvexity, equations (5.5) and (5.6) were re-estimated with curvature imposed using a method
described by Wiley, Schmidt, and Bramble (1973). This involved replacing the $A$ matrix by a lower triangular matrix $E$ and its transpose such that $A = E E^T$. A consequence of the procedure is that the unit profit function becomes nonlinear in some of the unknown parameters. The $a_{ik}$ parameters as specified in (5.4) can be retrieved from the coefficients of the $E$ matrix as per Table 5.5.

Because of nonlinearity in some of the unknown parameters with curvature imposed, the model was estimated using a nonlinear Quasi-Newton maximum likelihood procedure in a general computer program for econometric methods [White (1990)]. This procedure uses the Davidson-Fletcher-Powell algorithm to converge to a maximum. When using such a method, convergence to a local rather than global maximum is possible. For this reason, the model was estimated with starting values of unity and then re-estimated with starting values equal to five. Although not a test for a global maximum, both sets of starting values converged to the same final values.

The results of estimation of the unit profit function are presented in Table 5.5. The table presents estimates of the unknown parameters, their standard errors, the value of the log likelihood function, and the generalised $R^2$ for the system of equations estimated. The generalised $R^2$ is due to Baxter and Cragg (1970) and is defined by (5.7).

$$\text{Generalised } R^2 = 1 - \exp[2(L_0 - L_{\text{max}})/k]$$  \hspace{1cm} (5.7)

where $L_0$($L_{\text{max}}$) is the value of the log-likelihood function when all parameters are constrained to zero (unconstrained) and $k$ is the total number of observations.

Individual $r^2$ between observed and predicted values for the estimated equations are provided in Table 5.6. Consulting Table 5.6, apart from the other species output equation the individual $r^2$ are relatively high for cross-sectional data ranging from 0.57 to 0.71. It should be noted, however, that maximum likelihood estimation does
not in general maximise the individual $r^2$ values but minimises the determinant of the residual cross-products matrix. In addition, using the predicted outputs and inputs to construct predicted vessel profits per vessel, an $r^2$ of 0.47 was calculated between predicted and observed profits. Observation of the predicted output supplies and input demands revealed that the monotonicity condition was satisfied for every observation. Monotonicity is satisfied when all the predicted values of the input demands are negative and the predicted output supplies are positive.

To examine the robustness of the estimates to the choice of the functional form, a translog unit profit function was also estimated using the same set of data. This functional form represents a second order Taylor’s series approximation in logarithms of an arbitrary unit profit function. Such a profit function was first defined by Diewert (1974) and has been used in a fisheries context by Squires (1984, 1987) and by Bjørndal and Gordon (1989).

Imposing linear homogeneity, cross-price symmetry and an ad hoc dummy variable for the trap vessels, the function is defined by equation (5.8).

\[
\ln \Pi^R(P, Z_1) = \ln(P_1) + \alpha_0 + \sum_{i=2}^{N} \alpha_i \ln(P_i/P_1) + \alpha_2 \ln(Z_1) + \frac{1}{2} \alpha_{zz} [\ln(Z_1)]^2 + \frac{1}{2} \sum_{i=2}^{N} \alpha_{ii} [\ln(P_i/P_1)]^2 + \sum_{i=2}^{N} \alpha_{iz} \ln(P_i/P_1) \ln(Z_1) + \alpha_{23} \ln(P_2/P_1) \ln(P_3/P_1) + \alpha_{24} \ln(P_2/P_1) \ln(P_4/P_1) + \alpha_{34} \ln(P_3/P_1) \ln(P_4/P_1) + \sum_{i=2}^{N} \delta_i \ln(P_i/P_1) D \tag{5.8}
\]

where the variables are as defined previously, $\ln$ is a logarithmic transformation, and $\alpha_0, \alpha_i, \alpha_{ii}, \alpha_{ij}, \alpha_{iz}$ and $\delta_i$ are unknown parameters to be estimated.

Using Hotelling’s lemma the revenue and cost share equations may be obtained
by logarithmically differentiating (5.8) with respect to the input and output prices. By convention, the cost shares are affixed with a negative sign. For \( i = 2, 3, 4 \):

\[
W_i = \alpha_i + \sum_{k=2}^{N} \alpha_{ik} \ln\left(\frac{P_k}{P_1}\right) + \alpha_{i2} \ln(Z_1) + \delta_i D \tag{5.9}
\]

The system of equations to be estimated include (5.8) and \( N-1 \) share equations. Appending an additive disturbance term to equations (5.8) and (5.9), and using a maximum likelihood procedure, the parameter estimates, standard errors, value of the log likelihood function and a generalised \( R^2 \) for the system of equations are provided in Table 5.7. Individual \( r^2 \) between observed and predicted values for the estimated equations are given in Table 5.8. As with the normalised quadratic function, the translog fails to satisfy the appropriate curvature properties. Appropriate curvature properties were not, however, imposed on the function since it reduces the flexibility of the function and its ability to identify individual elasticities of substitution.

To obtain an estimate of the profits of fishers using the estimated profit functions it is necessary to subtract an appropriate share of the rental price for services provided by the restricted factor \( Z_1 \), i.e.,

\[
\Pi_S = \Pi_S^V(P, Z_1) - o[mZ_1] \tag{5.10}
\]

where \( \Pi_S \) is total sablefish profit, \( \Pi_S^V \) is variable sablefish profit, \( o \) is the factor for allocating indirect costs to sablefish operations, and \( m \) is the unit rental price of the fixed input of vessel length.

The factor used for allocating variable costs and overhead in 1988 was set equal to the ratio of direct costs attributable to sablefish as a proportion of total direct fishing costs. For 1990 predicted sablefish profits, the ratio equalled the proportion of predicted gross earnings from sablefish to gross earnings from all species. An estimate
of the rental price of the fixed factor was obtained from consultations with a fish boat trader and by reviewing commercial fishing magazines. Using quoted asking prices for comparable vessels from 1990 issues of the *West Coast Fisherman*, a median price per metre of comparable second-hand vessels used in the fishery was obtained. Such vessels would be the likely replacement for the current vessels used in the fishery. The median price of some $3,250/metre was then used to derive a flow rental price for the fixed input by assuming a straight line depreciation rate ($e$) and an interest rate faced by fishers of ($r$) per stock price ($v$), i.e.,

$$ m = v[e + r] $$

(5.11)

where it was assumed $r$ was 1% above the prime business lending rate and $e = 0.05$ on the assumption that on average vessels have a 20 year life after purchase. From the vessel lengths of vessels and a measure of the unit rental price ($m$), an estimate of total sablefish profits were obtained as per (5.10).

A comparison of the 1988 estimates of sablefish profits using the two profit functions is presented in Table 5.9. Both the normalised quadratic and translog functions give similar values for sablefish profits by gear-type, but exceed those obtained directly from the costs and earnings survey given in Tables 5.1 and 5.2. In particular, the estimated mean profit for trap and longline vessels with the normalised quadratic was some $327,000 and $107,000. The mean over all gear-types is some $189,000. For the translog function, the estimated mean profit was some $334,000 and $112,000, respectively, for the trap and longline vessels with the overall mean being $194,000. In comparison, using a direct approach to estimate the profits of fishers, the mean profits of trap and longline vessels was found to be $211,000 and $79,000 with an overall mean of $136,000. The difference between the measures of sablefish profit provided in Table 5.2 and 5.9 is, however, mostly explained by the different measures
of the value of assets employed in the fishery. For example, using the mean price per metre/vessel from the survey one may calculate another measure of the rental cost for the fixed factor. Using this rental price, the normalised quadratic and translog functions, respectively, estimate a mean sablefish profit for all fishers of some $143,000 and $149,000.

Using the predicted profits of vessels, an estimate of the total sablefish profits in the fishery may be obtained from the two profit functions. Such an estimate is not without problems since it presupposes that the sablefish profits of the vessels not in the costs and earnings survey are exactly the same per quantity of sablefish landed as those in the survey. Nevertheless, an estimate of total sablefish profits in 1988 is presented for comparison purposes. Table 5.10 presents the estimated rent that accrues to the vessel owners and is calculated by multiplying the total harvest in kg. for each vessel type by the mean sablefish profit/kg. for the two gear-types. The normalised quadratic and translog functions suggest that total sablefish profits were, respectively, some $8.6 million and $9.3 million in 1988. These estimates of the rent in the fishery reflect both resource and intra-marginal rents.

In assessing the sablefish profits in the fishery, it should be emphasised that the estimates reflect only the returns to the vessel owners. In the sablefish fishery, crew are generally paid on a share system equal to 50% of the total revenue less all operating expenses. As a result, it is likely that a share of the rents also accrue to labour. For example, in 1988 the average remuneration per crew-member from sablefish fishing alone was some $23,000 for less than 21 days work. This represents an amount approximately equal to the average annual earnings of manufacturing workers in British Columbia for that year. To obtain a measure of the rents that accrue to labour and vessel owners, a labour cost for sablefish crew based solely on an opportunity cost wage may be estimated. The total opportunity cost was calculated as an expected
average weekly earning per vessel based on their homeport multiplied by the number of weeks engaged in sablefish fishing by the crew. Using this approach, the calculated labour expenditures per vessel become equal to the actual labour costs in all other fisheries plus the opportunity cost wage for crew fishing for sablefish. Re-estimating the profit functions as described earlier with convexity imposed for the normalised quadratic function, an estimate of the rents to the vessel owners and labour may be obtained. For the translog function, the mean value for both gear-types was some $269,000 or some 40% more than that obtained using the actual labour expenditures of vessels. Using the normalised quadratic function, the mean value of the sablefish profits was some $260,000 or 37% more than that obtained using actual labour expenditures. It suggests that a substantial portion of the total resource rent in the sablefish fishery is received by the crew of vessels.

A justification for high earnings by crew members in a fishery is that it reflects a payment for the hazards of the job and for the risk involved in accepting a share of the gross returns rather than a fixed wage. Under a limited fishing season, where the skill and efforts of each crew member are important in determining the returns to the vessel and crew, a share system also helps to elicit effort that might otherwise not be forthcoming. Under individual quota management with a binding quota constraint, however, crew earnings can be known with a reasonable degree of certainty because vessels are reasonably assured of harvesting their annual quota. Further, without a limited fishing season vessel owners may be able to substitute crew skill for extra time at sea. Not unsurprisingly, therefore, there has been a move by some vessel owners to pay crew a daily wage rate rather than a share of gross revenue with the advent of individual vessel quotas [Dave Ellis, pers. com.]. A question that arises is why all vessels have not moved to a fixed wage payment of crew. A possible explanation for

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2 see Appendix B for details.
its continued existence is that the individual quota management scheme is in a trial period until the end of 1992. By changing or reducing the earnings of crew, quota-holders may attract attention from such organisations as the United Fishermen and Allied Workers' Union who have consistently opposed rights based management in BC. Such attention may provide further stimulus for lobbying against the current quota management scheme with DFO.3

Estimates of the 1990 sablefish profits of fishers from the two profit functions and for the two gear-types are provided in Table 5.11. The estimates are obtained from the predicted profits of 15 trap and 15 longline vessels that harvested sablefish in 1990 and represent the returns to the vessel owners only. These estimates were obtained by using the estimated coefficients of the respective profit functions and updating the input and output prices for 1990 and by specifying the vessel lengths and gear-type of the 30 vessels that participated in the fishery in 1990. Total sablefish profits in 1990 were calculated in a similar manner to 1988 by subtracting from predicted variable profit a rental cost per vessel. The share for allocating the wage and fuel expenditures to sablefish and rental cost of the fixed factor was set equal to the ratio of the predicted revenue from sablefish to total revenue from all species including sablefish. For both the normalised quadratic and the translog profit functions, all vessels fishing for sablefish in 1990 had positive profits. In the case of the normalised quadratic, the mean profit of vessels in 1990 was some $231,000 while for the translog function the mean vessel profits was some $223,000. The predicted total sablefish profits in 1990 for the fishery are presented in Table 5.12. For the normalised quadratic and translog functions, respectively, the total sablefish profits are some $7 million and $6.7 million.

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3The Union sponsored an inquiry into the BC fishing industry in 1991. The inquiry stated that the continued existence of the IVQ sablefish programme, "... should be contingent on an equitable share agreement between the quota-holder and crew members ... " [Cruickshank (1991), 68]
A comparison of the total sablefish profits in 1988 and 1990 in Tables 5.10 and 5.12 suggests that the rent fell from 1988 to 1990 despite the fact that the average profit per vessel of each gear-type increased over the period. This puzzling result stems from the fact that in 1990 there were 16 fewer vessels harvesting sablefish than there were in 1988 as a direct consequence of the introduction of transferable quotas. Most of the sablefish licence-holders who were not active in the fishery in 1990 leased their quota to other fishers. The estimated coefficients of the profit functions, however, are derived from 1988 data which does not account for the structural change that took place in the fishery in 1990 and the subsequent increase in sablefish harvests per vessel. Consequently, the predicted 1990 sablefish harvests of most vessels for both the normalised quadratic and translog functions underestimate the actual harvests in the fishery. For example, the actual harvest of all fishers in 1990 was some 4,260 MT while the normalised quadratic and translog functions, respectively, predict total harvests of 3,366 MT and 3,364 MT.

To obtain a measure of the total sablefish profits in the fishery accounting for the structural change in 1990, the predicted individual vessel sablefish profit/kg was multiplied by the actual harvest of each vessel in 1990. The estimates of the total sablefish profits, accounting for the structural change in the fishery, for both profit functions and by gear-type are presented in Table 5.13. The total sablefish profits for the normalised quadratic and translog profit functions calculated using this approach are, respectively, some $8.7 and $8.5 million and includes both the resource rent and intra-marginal rents. For the normalised quadratic, the total sablefish profits in 1990 exceed their value in 1988 while for the translog function the 1990 sablefish profits are less than in 1988.

Using the estimates given in Table 5.13, the proportion of total sablefish profit to total sablefish revenue in the fishery is some 49% and 47%, respectively, for the
normalised quadratic and translog profit functions. This compares favourably to studies in Australia which indicate potential rents in fisheries ranging from 25 to 60% of the gross landed value [Campbell and Haynes (1990)]. The estimates may also be compared to the rent that accrues to vessel owners under the traditional share system for paying crew. Under this system, 50% of the gross revenue accrues to the vessel's owner out of which must be met all indirect expenses. The upper bound for the sablefish profits in 1990 is, therefore, 50% of the gross landed value of sablefish that year or some $9 million.

Another approach to estimating the rent in the fishery in 1990 is to use the market price of quota. Depending upon the uncertainty in the fishery and the risk aversion of fishers, the resource rent should be equal to or greater than the annual value of quota holdings. Employing this approach, an estimate of the annual value of quota-holdings was obtained from a market price of quota for sablefish coupled with a sablefish fishing licence. This price, which varied from $8.94-9.30/kg over five transactions in 1990, was obtained from a Vancouver fish boat trader in early 1991 [K. Gaynor, pers. comm.]. Assuming an infinite pay-back period and multiplying the quota price by the total quota owned by fishers for 1990 and by an interest rate consistent with the opportunity cost of capital faced by fishers, an annual value of quota-holdings is calculated to be some $4.8 million. Assuming a pay-back period of five and ten years, the estimated annual resource rent that accrues to vessel owners is, respectively, some $11 and $7.2 million. This represents an estimate of the resource rent to vessel owners in the fishery less any discounting due to risk by fishers. Unlike an estimate of the total sablefish profits, however, the annual value of quota-holdings will not include any intra-marginal rents due to differential fishing skill or technology differences.
5.6 Overview

Three approaches are used to estimate the total rent in BC sablefish fishery in 1988. In a direct approach using data directly from a cost and earnings survey, the total fishery profits for 1988 are estimated to be $6.2 million with a lower range of $5.2 million. Using a licence value approach, the mean value of sablefish licences obtained from the CES was used to determine a capitalised value of the resource rent less an allowance for risk. Using a discount rate equal to the opportunity cost of capital faced by fishers, an estimate of the annual resource rent less discounting for risk was obtained of some $1.6 million. Assuming a different time horizon for fishers of only five and ten years, the annual resource rent that accrues to vessel owners is, respectively, some $3.7 and $2.4 million. In a third approach to estimating sablefish profits in 1988, a normalised quadratic and translog unit profit function were estimated. The mean profit per vessel for each gear-type from both functions gave a similar estimate to that using the direct approach after corrections were made for the use of different asset values. In total, the estimated sablefish profits in 1988 for the normalised quadratic and translog functions were some $8.6 and $9.3 million. All three approaches suggest there were substantial returns to be made in the BC sablefish fishery in 1988.

Updating output and input prices for 1990, the two profit functions were used to predict the individual profits of vessels in 1990. Under the translog specification total predicted sablefish profits are some $6.7 million while with the normalised quadratic function total sablefish profits are estimated to be some $7.0 million. Accounting for the structural change in the fishery between 1988 and 1990, an estimate of the total 1990 sablefish profits of $8.7 and $8.5 million is obtained, respectively, from the normalised quadratic and translog functions. This compares to an estimate of the sablefish profits using the traditional remuneration system in the fishery. Specifically,
vessel owners receive as a maximum return 50% of the gross landed value of sablefish out of which must be covered indirect expenses. This vessel share represents an upper bound for the estimated rents that accrue to vessel owners in the fishery and in total was some $9 million in 1990.

In an alternative measure of the rent in the fishery, the market price of quota in 1990 was used to estimate the total value of quota-holdings. Multiplying this total value by an interest rate equal to the opportunity cost of capital faced by fishers gives an estimate of the annual expected resource rent that accrues to vessel owners. Assuming an infinite time horizon or planning period by fishers the resource rent that accrues to vessel owners is estimated to be some $4.8 million. Assuming a different pay-back period, the annual resource rent that accrues to vessel owners is estimated to be $11 and $7.2 million, respectively, for a pay-back period of five and ten years.

In reviewing the various estimates of the rent in 1990, it would seem that the total sablefish profits that accrues to vessel owners is no more than $9 million and, if one accepts the predicted profits from the profit functions, it is some $8.5-8.7 million. Such a prediction compares favourably to an estimate of the annual resource rent that accrues to vessel owners using the traded quota price and assuming a ten year pay-back period. Using the normalised quadratic and translog profit functions predicted profits in 1990, with the adjustment for structural change in the fishery, the different methods of rent capture are examined in chapter 6.
### Table 5.1: 1988 Summary Statistics of Fishers

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>C.V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel Profits</td>
<td>231,144</td>
<td>51,885</td>
<td>839,390</td>
<td>0.675</td>
</tr>
<tr>
<td>Sablefish Profits</td>
<td>136,030</td>
<td>30,398</td>
<td>703,640</td>
<td>0.955</td>
</tr>
<tr>
<td>Price of Sablefish</td>
<td>3.71/kg</td>
<td>3.29</td>
<td>4.47</td>
<td>0.067</td>
</tr>
<tr>
<td>Price of Fuel</td>
<td>0.34792/litre</td>
<td>0.3179</td>
<td>0.3790</td>
<td>0.063</td>
</tr>
<tr>
<td>Kilos of Sablefish</td>
<td>104,070</td>
<td>33,408</td>
<td>319,260</td>
<td>0.720</td>
</tr>
<tr>
<td>Kilos of Other Fish</td>
<td>354,640</td>
<td>0</td>
<td>2,963,800</td>
<td>2.284</td>
</tr>
<tr>
<td>Crew size (excluding skipper)</td>
<td>3.85</td>
<td>0</td>
<td>12</td>
<td>1.28</td>
</tr>
<tr>
<td>Vessel Length</td>
<td>19.32 m</td>
<td>10.01</td>
<td>37.19</td>
<td>0.331</td>
</tr>
<tr>
<td>Vessel Registered Tonnage</td>
<td>34.64</td>
<td>7</td>
<td>194.71</td>
<td>1.091</td>
</tr>
<tr>
<td>Vessel Age</td>
<td>17 years</td>
<td>7</td>
<td>48</td>
<td>0.78614</td>
</tr>
<tr>
<td>Value Sablefish Licences</td>
<td>277,310</td>
<td>100,000</td>
<td>600,000</td>
<td>0.427</td>
</tr>
<tr>
<td>Sablefish Revenue</td>
<td>385,870</td>
<td>121,910</td>
<td>1,293,000</td>
<td>0.743</td>
</tr>
<tr>
<td>Direct Fishing Expenses</td>
<td>314,620</td>
<td>84,400</td>
<td>830,400</td>
<td>0.567</td>
</tr>
<tr>
<td>Indirect Expenses</td>
<td>97,176</td>
<td>15,700</td>
<td>263,520</td>
<td>0.784</td>
</tr>
</tbody>
</table>

Sources:

1. DFO 1988 costs and earnings survey of 28 sablefish licence-holders.
2. DFO 1988 catch statistics.
3. Chevron Canada.
4. Vancouver Ship Registry.
### Table 5.2: Estimates of 1988 Mean Net Returns and Profitability Ratios using the Survey Data Directly

<table>
<thead>
<tr>
<th>Measure</th>
<th>Trap</th>
<th>Longline</th>
<th>All Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sablefish Profit:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>211,490</td>
<td>79,430</td>
<td>136,030</td>
</tr>
<tr>
<td>Median</td>
<td>184,448</td>
<td>69,724</td>
<td>99,960</td>
</tr>
<tr>
<td>Sablefish Profit/Sablefish Revenue:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>33%</td>
<td>37%</td>
<td>35%</td>
</tr>
<tr>
<td>Median</td>
<td>30%</td>
<td>36%</td>
<td>33%</td>
</tr>
<tr>
<td>Vessel Profit/Equity:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>26%</td>
<td>38%</td>
<td>33%</td>
</tr>
<tr>
<td>Median</td>
<td>22%</td>
<td>32%</td>
<td>25%</td>
</tr>
<tr>
<td>Sablefish Profit/Sablefish Landed:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>$1.20 kg</td>
<td>$1.38 kg</td>
<td>$1.30 kg</td>
</tr>
<tr>
<td>Median</td>
<td>$1.04 kg</td>
<td>$1.35 kg</td>
<td>$1.21 kg</td>
</tr>
</tbody>
</table>
Table 5.3: Predicted Mean Sablefish Profit for Non CES Vessels in 1988 ($) using Sablefish Landings and Age of Vessel Data

<table>
<thead>
<tr>
<th>Gear-Type</th>
<th>No. Vessels</th>
<th>Mean Profit</th>
<th>Lower 95% C.I</th>
<th>Upper 95% C.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trap</td>
<td>10</td>
<td>189,647</td>
<td>105,508</td>
<td>273,786</td>
</tr>
<tr>
<td>Longline</td>
<td>8</td>
<td>63,865</td>
<td>44,080</td>
<td>83,649</td>
</tr>
</tbody>
</table>

Table 5.4: Direct Estimates of Total Sablefish Profits in 1988 ($) using Survey Data and Sablefish Landings and Age of Vessel Data

<table>
<thead>
<tr>
<th>Data Source</th>
<th>No. Vessels</th>
<th>Sablefish Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>CES</td>
<td>28</td>
<td>3,809,000</td>
</tr>
<tr>
<td>Non CES</td>
<td>18</td>
<td>2,407,000</td>
</tr>
<tr>
<td>All Vessels</td>
<td>46</td>
<td>6,216,000</td>
</tr>
</tbody>
</table>
Chapter 5. Rent and the BC Sablefish Fishery

Table 5.5: Nonlinear Parameter Estimates of the Normalised Quadratic Unit Profit Function

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Std. Error</th>
<th>Variable</th>
<th>Value</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>eff</td>
<td>-264.19</td>
<td>95.03</td>
<td>c4z</td>
<td>0.23517E+06</td>
<td>0.27871E+06</td>
</tr>
<tr>
<td>eof</td>
<td>90.58</td>
<td>70.46</td>
<td>c1</td>
<td>94,163</td>
<td>96,277</td>
</tr>
<tr>
<td>eoo</td>
<td>192.92</td>
<td>103.81</td>
<td>c2</td>
<td>18,322</td>
<td>13,447</td>
</tr>
<tr>
<td>esf</td>
<td>176.43</td>
<td>172.05</td>
<td>c3</td>
<td>3,243</td>
<td>93,243</td>
</tr>
<tr>
<td>eso</td>
<td>577.58</td>
<td>186.89</td>
<td>c4</td>
<td>-0.26092E+06</td>
<td>0.11617E+06</td>
</tr>
<tr>
<td>ess</td>
<td>-0.10989E-04</td>
<td>762.77</td>
<td>d1</td>
<td>-65,967</td>
<td>52,425</td>
</tr>
<tr>
<td>c1z</td>
<td>-0.15166E+06</td>
<td>0.21385E+06</td>
<td>d2</td>
<td>-26,890</td>
<td>8,048</td>
</tr>
<tr>
<td>c2z</td>
<td>-36,539</td>
<td>72,492</td>
<td>d3</td>
<td>-275.89</td>
<td>44,234</td>
</tr>
<tr>
<td>c3z</td>
<td>0.20809E+06</td>
<td>0.14826E+06</td>
<td>d4</td>
<td>0.21417E+06</td>
<td>77,767</td>
</tr>
</tbody>
</table>

Note:

1. Log-likelihood function = -1351.245

2. Generalised $R^2 = 0.64$

3. The $a_{ik}$ coefficients of the profit function are obtained as follows: $a_{22} = eff^2$, $a_{23} = eff \times eof$, $a_{24} = eff \times esf$, $a_{33} = eof^2 + eoo^2$, $a_{34} = eof \times esf + eoo \times eso$, $a_{44} = esf^2 + eso^2 + ess^2$. 
Table 5.6: R-Square Values for Normalised Quadratic Profit Function

<table>
<thead>
<tr>
<th>Equation</th>
<th>R-Square between Observed &amp; Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour Demand</td>
<td>0.5942</td>
</tr>
<tr>
<td>Fuel Demand</td>
<td>0.5719</td>
</tr>
<tr>
<td>Other Species Output</td>
<td>0.1012</td>
</tr>
<tr>
<td>Sablefish Output</td>
<td>0.7127</td>
</tr>
<tr>
<td>Profit</td>
<td>0.4667</td>
</tr>
</tbody>
</table>
### Table 5.7: Parameter Estimates of the Translog Unit Profit Function

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
<th>Std. Error</th>
<th>Variable</th>
<th>Value</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_0$</td>
<td>6.8968</td>
<td>6.538</td>
<td>$\alpha_{23}$</td>
<td>-0.9231E-02</td>
<td>0.5936E-01</td>
</tr>
<tr>
<td>$\alpha_2$</td>
<td>-0.1982</td>
<td>0.3028</td>
<td>$\alpha_{24}$</td>
<td>0.2894</td>
<td>0.1395</td>
</tr>
<tr>
<td>$\alpha_3$</td>
<td>1.0977</td>
<td>1.0403</td>
<td>$\alpha_{34}$</td>
<td>0.6289E-01</td>
<td>0.2834</td>
</tr>
<tr>
<td>$\alpha_4$</td>
<td>0.7493</td>
<td>1.198</td>
<td>$\alpha_{2z}$</td>
<td>-0.8292E-01</td>
<td>0.694E-01</td>
</tr>
<tr>
<td>$\alpha_z$</td>
<td>1.497</td>
<td>4.36</td>
<td>$\alpha_{3z}$</td>
<td>-0.4431E-01</td>
<td>0.3911</td>
</tr>
<tr>
<td>$\alpha_{22}$</td>
<td>0.1059E-01</td>
<td>0.1517</td>
<td>$\alpha_{4z}$</td>
<td>0.29953</td>
<td>0.34458</td>
</tr>
<tr>
<td>$\alpha_{33}$</td>
<td>-0.1664</td>
<td>0.3583</td>
<td>$\delta_2$</td>
<td>-0.1169E-02</td>
<td>0.3465E-01</td>
</tr>
<tr>
<td>$\alpha_{44}$</td>
<td>-0.1818</td>
<td>0.5921</td>
<td>$\delta_3$</td>
<td>-0.4272</td>
<td>0.1899</td>
</tr>
<tr>
<td>$\alpha_{zz}$</td>
<td>-0.1979</td>
<td>1.4656</td>
<td>$\delta_4$</td>
<td>0.1736</td>
<td>0.99731E-01</td>
</tr>
</tbody>
</table>

**Note:**

1. Log-likelihood function = 28.65
2. Generalised $R^2 = 0.89$
Table 5.8: R-Square Values for Translog Unit Profit Function

<table>
<thead>
<tr>
<th>Equation</th>
<th>R-Square between Observed &amp; Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit</td>
<td>0.3411</td>
</tr>
<tr>
<td>Fuel Demand</td>
<td>0.1416</td>
</tr>
<tr>
<td>Other Species Output</td>
<td>0.3016</td>
</tr>
<tr>
<td>Sablefish Output</td>
<td>0.1311</td>
</tr>
</tbody>
</table>
Table 5.9: Estimated Mean 1988 Sablefish Profits ($) for Profit Functions

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Trap Vessels</th>
<th>Longline Vessels</th>
<th>All Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalised Quadratic</td>
<td>327,000</td>
<td>107,000</td>
<td>189,000</td>
</tr>
<tr>
<td>Translog</td>
<td>334,000</td>
<td>112,000</td>
<td>194,000</td>
</tr>
</tbody>
</table>

Table 5.10: Estimated Total 1988 Sablefish Profits ($) for Profit Functions

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Trap Vessels</th>
<th>Longline Vessels</th>
<th>All Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalised Quadratic</td>
<td>6,177,000</td>
<td>2,489,000</td>
<td>8,666,000</td>
</tr>
<tr>
<td>Translog</td>
<td>6,672,000</td>
<td>2,661,000</td>
<td>9,333,000</td>
</tr>
</tbody>
</table>
### Table 5.11: Predicted Mean 1990 Sablefish Profits ($) for Profit Functions

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Trap Vessels</th>
<th>Longline Vessels</th>
<th>All Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalised Quadratic</td>
<td>330,000</td>
<td>132,000</td>
<td>231,000</td>
</tr>
<tr>
<td>Translog</td>
<td>300,000</td>
<td>145,000</td>
<td>223,000</td>
</tr>
</tbody>
</table>

### Table 5.12: Predicted Total Sablefish Profits in 1990 ($) for Profit Functions

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Trap Vessels</th>
<th>Longline Vessels</th>
<th>All Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalised Quadratic</td>
<td>4,946,000</td>
<td>1,976,000</td>
<td>6,960,000</td>
</tr>
<tr>
<td>Translog</td>
<td>4,505,000</td>
<td>2,180,000</td>
<td>6,685,000</td>
</tr>
</tbody>
</table>

### Table 5.13: Predicted Total Sablefish Profits in 1990 ($) from the Unit Profit Functions and Accounting for Structural Change

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Trap Vessels</th>
<th>Longline Vessels</th>
<th>All Vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalised Quadratic</td>
<td>6,589,000</td>
<td>2,111,000</td>
<td>8,670,000</td>
</tr>
<tr>
<td>Translog</td>
<td>6,536,000</td>
<td>1,952,000</td>
<td>8,489,000</td>
</tr>
</tbody>
</table>
Chapter 6

Rent Capture Methods and the BC Sablefish Fishery

A tax upon the rent of land which varies with every variation of the
rent, ... , is recommended by the sect of men of letters in France, who
call themselves the œconomists, as the most equitable of all taxes.

Adam Smith (1723-1790) An Inquiry into the Nature and Causes of the Wealth of

6.1 Introduction

This chapter uses the estimates of the sablefish profits of fishers in chapter 5 to assess
the effects of different methods of rent capture on the BC sablefish fishery in 1990.
The purpose of the analysis is to explore the implications of rent capture for the fish-
ery and in particular the distribution of profits by fishers and gear-type. Wherever
possible, the empirical results and findings will be compared to those obtained using
the theoretical model. In this approach, the assumption of short-run profit maximisa-
tion for a given capital stock with no uncertainty is preserved as is the notion of two
types of fishers using different harvesting technologies. The two types are represented
by fishers who use either pots or traps, or bottom longline gear. The empirical analy-
sis, however, does not address uncertainty or rent collection costs and its implications
for rent capture.

The methods of rent capture examined in this chapter include a quota rental
charge, profit charge, net cash flow charge, \textit{ad valorem} royalty, and a lump sum fee. A quota transfer charge is not compared to the other rent capture schemes as it has been shown in the theoretical model to affect both the number of trades and the quota price. Consequently, analysing its effects with the equilibrium existing in 1990 would be misleading. The effects of an auction on the fishery is not examined as it would also require imposing additional assumptions with respect to the post auction quota distribution and auction price.

In comparing the various methods of rent capture, individual predicted profits of fishers for 1990 from the normalised quadratic and translog profit functions are used. The predicted profits for the two profit functions include an adjustment to reflect the structural change in the fishery brought about by individual quota management. The estimated mean profits by gear-type for the normalised quadratic and translog are presented in Table 5.13. Using the two estimates of the 1990 sablefish profits, each rent capture scheme is compared at equivalent rates of rent capture of 10, 20, 30, 40, 50, and 90%. These rates of rent capture are referenced to the predicted sablefish profits of fishers and may include both a resource rent and intra-marginal rents. In the case of the normalised quadratic, a 10% rate of rent capture is equivalent to collecting some $867,000, while a 90% rate of rent capture collects some $7.8 million. For the translog function, the rent collected represents some $849,000 at a 10% rate of rent capture and $7.64 million at a 90% rate of rent capture.

Tables 6.1-6.5 present the mean, standard deviation, the range, and the number of fishers facing losses under each scheme for each rate of rent capture. The profits represent the sablefish profits after imposition of the method of rent capture at the given charge rate. The quota rental charge is calculated by multiplying the individual harvests of vessels by an identical amount per kg such that the total rent collected is the same for the other rent capture schemes. It differs, therefore, from the charge
specified in chapter 4 because it may capture both resource and intra-marginal rents. The rent collected with a profit charge is determined by multiplying the predicted sablefish profits by the specific rates of rent capture of 10% to 90%. The net cash flow charge is set at a fixed proportion for all vessels and at a level that collects the same rent from the fishery as the other rent capture schemes. The net cash flow of vessels is assumed to equal the predicted variable sablefish profits. An *ad valorem* royalty charge is calculated as a proportion of the harvest of fishers multiplied by the price of sablefish faced by fishers. This is not the same as an *ad valorem* royalty where fishers face the same output price or are charged on the basis of an average output price for the fleet. Finally, a lump sum charge is set by dividing the total amount of rent to be collected by the number of vessels fishing for sablefish in 1990. This amount, the same for all fishers, is subtracted from predicted sablefish profits to obtain the profits of vessels after imposition of the lump sum fee.

Using the predicted fisher profits in Tables 6.1-6.5, the burden of the different types of rent capture and distribution of profits are examined. In a separate section, the effects of rent capture on the quota equilibrium in the fishery are also addressed.

### 6.2 Fisher Profits

Examining Tables 6.1-6.5 it can be seen that the estimates of the post-rent capture profits of fishers are similar for both the translog and normalised quadratic profit functions. Using the normalised quadratic estimates, one may rank the rent capture methods according to the total amount of rent paid by each type of vessel. On this basis, trap vessels collectively prefer in descending order of preference a lump sum fee, *ad valorem* royalty, net cash flow charge, profit charge, and a quota rental charge. In contrast, the longline vessels collectively prefer in descending order of preference
a quota rental charge, profit charge, net cash flow charge, *ad valorem* royalty, and a lump sum fee. The translog provides a similar ordering with the exception that the ordering of the profit charge and quota rental charge are reversed for the trap and longline vessels.

A closer examination of the predicted profits reveals the reasons for the differences in the rental paid by the two types of vessels. A comparison of Tables 6.1 and 6.2, shows that with the normalised quadratic, trap vessels collectively pay less rent with a profit charge than a quota rental charge while the opposite is true for the longline vessels. Following proposition 4.4, one would expect that the trap vessels collectively would have a lower predicted profit per quantity of sablefish landed than the longline vessels. This is indeed the case with the sablefish profits being $1.94/kg and $2.00/kg, respectively, for the trap and longline vessels. In this scenario, those fishers who have higher net earnings per quantity of sablefish are relatively better off with a quota rental charge compared to an equivalent profit charge. Using the translog profit function, trap vessels collectively are predicted to have sablefish profits of $1.95/kg, while longline vessels collectively have profits of $1.88/kg. Using these values, the trap vessels collectively have the higher profits per quantity of sablefish and consequently will prefer a quota rental charge over an equivalent profit charge.

A comparison can also be made between the quota rental charge and a lump sum fee. In 1990, there were 15 trap and 15 longline vessels operating in the fishery. Imposing a lump sum fee of an equal amount on all vessels that harvested sablefish generates the figures presented in Table 6.5. Using the normalised quadratic estimates, fishers pay a rental of $29,000 at a 10% rate of rent capture and $261,000 at a 90% rate of rent capture. In the case of the longline vessels, a rate of rent capture at only 50% of the predicted sablefish profits results in a loss for 9 of the 15 longline vessels operating in the fishery. The burden imposed on longline vessels with a lump
sum fee is a direct result of their low quota-holdings relative to that of trap vessels. Collectively, longline vessels harvested some 24% of the TAC while trap vessels harvested the remainder. Following proposition 4.5, therefore, a quota rental charge will be preferred over a lump sum fee by longline vessels while the reverse is the case for trap vessels. It can also be shown that the proportion of the total sablefish profit and net cash flow in the fishery accounted for by longline vessels in 1990 is predicted to be some 24%. As this proportion is less than the proportion of vessels liable for a lump sum charge, a profit and net cash flow charge will also be preferred by longline vessels. This is also true of the *ad valorem* royalty where longline vessels collectively account for 27% of the gross landed value of sablefish in the fishery.

A comparison between the *ad valorem* royalty and quota rental charge also reveals some important differences between charging a royalty on the average landed price and the price actually received by fishers. In the case where fishers are charged on an average output price for the fishery, an *ad valorem* royalty and quota rental charge are identical by proposition 4.1. If, however, the *ad valorem* royalty charge is based upon the actual price received for sablefish which differs across vessels, the two rent capture schemes will differ. For example, using the predicted sablefish profits of vessels, one fisher is found to pay $259,000 with an *ad valorem* royalty at 90% rent capture while with a quota rental charge at the same rate of rent capture the same fisher pays some $406,000. In contrast, another fisher is found to pay some $511,000 with an *ad valorem* royalty at 90% rent capture but pays only $295,000 with a quota rental charge. The difference between the two methods of rent capture is entirely based upon the price received for sablefish by the fishers relative to the average price for the sablefish fishing fleet. Those fishers who receive a lower than average price for their output will be relatively favoured with an *ad valorem* royalty compared to a quota rental charge. For example, the fisher who pays less with the *ad valorem* royalty
received a mean price for sablefish of $2.61/kg while the average price over all thirty vessels in the sablefish fleet was some $3.97/kg. A comparison can also be made with respect to the two types of vessels in the sablefish fleet. Collectively, longline vessels receive a higher price for their sablefish ($4.13/kg.) than trap vessels ($3.90/kg.). As a result, longline vessels as a group are relatively better off with a quota rental charge than an *ad valorem* royalty. The reverse is true for trap vessels who collectively prefer an *ad valorem* royalty over a quota rental charge.

A comparison may also be made between a quota rental charge and a net cash flow charge. From proposition 4.3, those fishers with a higher than average ratio of the value of their quota-holdings to net cash flow will pay more with a quota rental charge than an equivalent net cash flow charge. Using the normalised quadratic estimates, trap vessels collectively have a ratio of the value of quota-holdings to net cash flow of some 4.57 while longline vessels collectively have a ratio of 4.42. Consulting Tables 6.1 and 6.3, it can be shown that as predicted, trap vessels collectively prefer a net cash flow charge while longline vessels collectively prefer a quota rental charge.

A related issue to the distribution of the burden of the different rent capture schemes is the degree of concentration around the mean profit for the fleet. Consulting Tables 6.1-6.5, the standard deviation of the post-rent capture profits of fishers for the different rent capture schemes is presented. In the case of a lump sum charge, the standard deviation of the profits of fishers of both gear-types is unaltered by the rate of rent capture. This is a direct result of the fact that subtracting a constant from every observation in a sample will leave the variance unchanged. In contrast, subtracting an equal proportion from every observation will reduce the variance of a sample. As a result, the greater the level of rent capture with a profit charge the greater will be the degree of concentration around the mean and the lower will be the variance of fisher profits. Examining the standard deviation of profits of fishers
with a quota rental charge and net cash flow charge also reveals that, in the fishery, increasing the rate of rent capture will increase the degree of concentration around the mean profit. Unlike with the profit charge, however, this is not a general result such that increasing the rate of rent capture may actually increase the variance of fisher profits. This is also true for an *ad valorem* royalty and is illustrated in Table 6.4 where for longline vessels the variance of profits actually increases as the rate of rent capture rises from 50% to 90%.

### 6.3 Distortions to the Fishery

An issue as important as the relative burdens of the different methods of rent capture is the effect of rent capture on the short-run quota equilibrium. In the empirical analysis, distortions from rent capture are addressed by the losses imposed upon fishers. In this approach, if a method of rent capture imposes losses on certain fishers at the short-run quota equilibrium then the supposition is that such individuals will be driven from the fishery. The exit of such fishers, at least in the short-run, will reduce the total sablefish profits because quota-trading should already have allowed fishers to trade such that the marginal value of additional quota was the same for all fishers.

The method of rent capture that appears to distort the quota equilibrium the most is a lump sum charge. Observation of Table 6.5 reveals that at relatively low levels of rent capture a lump sum fee leaves a number of fishers with losses. For example, using the normalised quadratic and translog profit functions, respectively, some 17% and 20% of the total number of vessels face losses at a rate of rent capture of only 30% of total sablefish profits. The fishers facing losses at this rate of rent capture, however, are not necessarily the least profitable fishers but rather those fishers with
Chapter 6. Rent Capture Methods and the BC Sablefish Fishery

relatively smaller quota-holdings and consequently smaller total profits. For instance, at a 30% rate of rent capture one of the vessels facing a loss has one of the highest ratios in the fleet of profit per kg. of sablefish harvested.

Comparing the effects of lump sum fee on gear-types, it should be noted that it is longline vessels that generally have smaller quota-holdings relative to trap vessels. As a result, imposition of a lump sum fee would have the effect of driving longline vessels from the fishery. Using the predictions from the normalised quadratic at a 90% rate of rent capture, it is found that only 2 out of the 15 longline vessels previously fishing for sablefish would remain in the fishery after imposing a lump sum charge. At this same rate of rent capture, six trap vessels would also face losses such that just over one third of the fleet would have positive profits. A consequence of forcing profitable fishers with small quota-holdings from the fishery is to favour those fishers with large quota-holdings and with higher absolute profits. Using the normalised quadratic estimates, for example, the fisher with the largest quota-holdings has a profit of some $814,000 at a 90% rate of rent capture and pays a rental charge equal to only 24% of the total profit before rent capture.

In contrast to the lump sum charge, a profit charge and net cash flow charge are shown to leave fishers with positive profits irrespective of the rate of rent capture. The exception being one of the trap vessels with a net cash flow charge at a rate of rent capture of 90% using the estimates from the normalised quadratic profit function. It illustrates an interesting result that a net cash flow charge imposed uniformly on all vessels at a rate that collects less than the total profits can still leave certain fishers with a loss. The individuals that would incur losses with a net cash flow charge would be owners of vessels with the highest ratio of net cash flow to profits. Such vessels would be characterised by relatively high fixed or indirect costs but not necessarily low profits per quantity of sablefish harvested. In the case of a profit charge, provided
that profits are estimated correctly, such a method of rent capture would never leave those fishers that have positive pre-rent capture profits with a loss.

The other methods of rent capture to be considered include an *ad valorem* royalty and a quota rental charge. Consulting Table 6.4 for the normalised quadratic estimates, an *ad valorem* royalty leaves no fishers with a loss at a 50% rate of rent capture but imposes losses on five vessels at a 90% rate of rent capture. Using the translog estimates, one longline vessel experiences a loss at a 50% rate of rent capture and three vessels experience a loss at a 90% rate of rent capture. Those vessels experiencing the losses are the quota-holders with the lowest ratio of sablefish profits to gross revenue from sablefish. For example, the average proportion of profit to gross revenue for the vessels incurring losses is some 33% while the average for the fleet is some 49%. Most of these vessels also have some of the lowest profits per sablefish landed in the fleet. The correlation between vessels with low profits per quantity of sablefish and low profits as a proportion of gross revenue is not, however, perfect. For instance, there are fishers with lower profits per sablefish landed than some of the vessels experiencing losses with an *ad valorem* royalty at a 90% rate of rent capture but who have positive profits at the same rate of rent capture.

Using the normalised quadratic estimates, a quota rental charge imposes losses on one trap vessel at a 40% rate of rent capture, on two trap vessels at 50% rent capture, and on four trap and two longline vessels at a 90% rate of rent capture. Using the translog estimates, only at a rate of rent capture of 90% are there vessels experiencing losses of which four are trap vessels and five longline vessels. In the quota rental charge it is those vessels with the lowest sablefish profit per kg. of sablefish harvested that incur losses at the high rates of rent of capture. For example, using the normalised quadratic estimates the six vessels experiencing losses at a rate of rent capture of 90% receive a mean sablefish profit per kg. harvested of $1.34 compared
The existence of fishers with losses with a quota rental charge at less than a 100% rate of rent capture is an interesting result because such a method of rent capture should only collect the resource rent that accrues to quota-holders. It should not, therefore, leave fishers with losses after imposition of the charge. The result arises from the fact that the quota rental charge is set at a level where at a 90% rate of rent capture much more than the expected resource rent will be collected. For example, using an interest rate of 11.83%, a quota price of $9.3/kg, and a long term planning horizon by fishers, an estimate of the annual resource rent in the fishery is some $4.8 million. This represents some 55% and 56%, respectively, of the total predicted sablefish profits using the normalised quadratic and translog functions.

Given that the assumptions used to estimate the annual resource rent in the fishery are appropriate, it would suggest that quasi-rents in the fishery represent somewhat less than half the total sablefish profits. Imposition of a quota rental charge that collects more than $4.8 million such that the quota rental charge rate is greater than unity will, therefore, collect some intra-marginal rent and may leave certain fishers with losses. Using the normalised quadratic, a quota rental charge, and a rate of rent capture such that no more than the estimated resource rent of $4.8 million is collected from the fishery, there are just two trap vessels with predicted losses. Using the translog estimates, there is only one vessel with a predicted loss. This result is interesting as it suggests that there may be fishers who face a loss with a quota rental charge that collects no more than 100% of the estimated annual value of quota-holdings. The result may be an error in prediction in the profit functions or may reflect the fact that there may indeed be fishers prepared to accept short-term losses in terms of economic profits. Such fishers would, \textit{ex-post} have been better off selling or leasing their quota to another fisher and investing the proceeds elsewhere in
Chapter 6. Rent Capture Methods and the BC Sablefish Fishery

the economy. For such fishers, there may be non pecuniary benefits associated with fishing, or they may simply have had lower than expected earnings from using their sablefish quota themselves.

An important issue addressed in the examination of the quota rental charge is the separation of resource and intra-marginal rents. In earlier chapters, it was stressed that collecting intra-marginal rents may impose certain costs in terms of efficiency that capturing the resource rent may not. In practice, however, separating the two rents in an estimate of the profits of fishers is a difficult if not impossible task. If there exists a competitive quota market where quota is freely tradeable then an estimate of the present value of the expected resource rent less any discounting because of risk should be reflected in the quota price. Multiplying the total quota-holdings by the traded quota price, in turn, provides an estimate of the present value of the expected resource rent less any discounting because of risk. To obtain an estimate of the annual expected resource rent one must impose assumptions with respect to the discount rate used by fishers and the expected pay-back period. Using a rate of discount equal to the assumed opportunity cost of capital faced by fishers, various estimates of the expected resource rent can be obtained depending upon the pay-back period. Assuming a five year pay-back period, the annual expected resource rent less any discounting because of risk is some $11 million, assuming a ten year pay-back it is some $7.2 million, and with an infinite pay-back period it is some $4.8 million.

If the resource owner wishes to minimise the likelihood of capturing intra-marginal rents, therefore, it may be preferable to use lower estimates of the expected resource rent and capture a share of such an amount and leave the remaining rents in the fishery. In such a situation, a preferred method for collecting the rent is one which does not capture the intra-marginal rents. Provided there exists a competitive quota market, an obvious way to collect only the expected resource rent less any discounting
because of risk is to use a quota rental charge. From proposition 4.1, an equivalent
*ad valorem* royalty based on the average output price for the fleet would also collect
the same amount from each fisher. In comparison, other methods of rent capture,
such as a profit charge or net cash flow charge, force fishers to pay a rental in equal
proportion although the share of the resource rent accruing to fishers will differ across
the fleet. For example, for a particular fisher if half the profits are attributable to his
or her own fishing skills then at a high rate of rent capture with a profit charge the
fisher will pay all the resource rent and most of the intra-marginal rent. In contrast, a
fisher earning only resource rents and no intra-marginal rent will with a profit charge
still retain a share of the resource rent even at a high rate of rent capture.

In a related issue, imposing rent capture requires estimates of the profits and rents
in the fishery. In the case of the sablefish fishery, two estimates of individual vessel
profits are used for examining the consequences of rent capture. In any approach to
estimating the profits of fishers, however, there must exist some measurement error.
If the discrepancy between the estimated profits and actual profits is sufficiently
large, there exists the possibility of capturing more than just rent from the fishery.
If avoiding the possibility of capturing more than rent from fishers is a priority, the
greater the expected error in estimating the profits of fishers then, *ceteris paribus*,
the lower should be the intended rate of rent capture.

Another concern in capturing more than rent from the fishery is the issue of
quota-trading prior to the introduction of a rent capture scheme. If a method of rent
capture is introduced subsequent to quota-trading and where there was no expectation
of rent collection, the new owner will have paid the previous quota-holder an amount
exceeding the expected resource rent net of rental payments. Imposing any method
of rent capture on the fishery will, therefore, result in the capture of some of the
intra-marginal rents of fishers or even losses for some of the new quota-holders. In
the short run this may reduce the total rent in the fishery as otherwise profitable and skilled fishers are forced to exit the fishery. To avoid such distortions, therefore, it is advisable to announce the type and rate of rent capture prior to quota trading. In the case of the BC sablefish fishery, much of the trading since the introduction of ITQ's has involved the leasing of quota from one fisher to another. This is in part explained by a restriction by the regulator not to allow any permanent transfers of quota during a defined trial period for the management scheme [Canada Department of Fisheries and Oceans (1990b)]. Despite the regulation there have, however, been five permanent transfers of quotas which have circumvented the injunction by the outright purchase of a sablefish licence with the attached quota. For such vessel owners, imposition of a method of rent capture in the future may prove problematic.

In summary, it would seem that a lump sum charge is potentially one of the more distorting methods of rent capture for the sablefish fishery. In comparison, a profit charge does not leave fishers with losses at any rate of rent capture but is capable of collecting intra-marginal rents from some fishers while leaving others with a share of the resource rent. A quota rental charge is found to leave certain fishers with losses at rates of rent capture more than 40% while an \textit{ad valorem} royalty has this feature at rates of rent capture more than 50%. A quota rental charge also has the potential to collect only the expected resource rent.

6.4 Overview

The examination of the different methods of rent capture in the BC sablefish fishery illustrates some of the important results of the thesis. It is also the first empirical examination of different methods of rent capture in a rights based fishery. As such it provides resource owners with a framework for comparing and evaluating methods of
rent capture in other fisheries.

In the BC sablefish fishery, it is shown that the gear-type used by fishers has an effect on the rental paid under the various rent capture schemes. Using the normalised quadratic function, trap fishers collectively prefer in descending order of preference a lump sum charge, ad valorem royalty, net cash flow charge, profit charge and a quota rental charge. In contrast, longline vessels have a reverse ordering for the rent capture schemes. The relative preference for one rent capture scheme over another is dependent on the various characteristics of the vessels. For instance, longline vessels are collectively shown to prefer a quota rental charge as they earn a higher profit per kg. of sablefish harvested than trap vessels. Similarly, trap vessels collectively prefer a lump sum charge over a quota rental charge as the proportion of the total quota that they own exceeds their proportion of the total number of fishers.

The chapter also addresses the effects of distortions that might arise from collecting rent from the fishery. Using the number of fishers who face post-rent capture losses as an indicator of the distortion to the short-run quota equilibrium, a lump sum charge is shown to imposes inefficiencies on the fishery at relatively low rates of rent capture. In particular, it imposes rental charges that are relatively more burdensome on fishers with smaller quota-holdings, most of whom use longline gear. Another important issue that is examined is the distinction between resource rent and intra-marginal rents. Using an estimate of the expected annual resource rent less any discounting because of risk, the relative break-down of profits into intra-marginal rent and resource rent is attempted. Provided that there exists a competitive quota market and price for quota, a quota rental charge may be a suitable means for trying to capture the expected resource rent less any discounting because of risk.
Table 6.1: Predicted 1990 Profits of Fishers at Different Levels of Rent Capture with a Quota Rental Charge using a Normalised Quadratic and Translog Profit Functions ($)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>90%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Norm. Quadratic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Trap:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>395,090</td>
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<td>306,740</td>
<td>262,570</td>
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<td>Min</td>
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<td>-257,310</td>
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<td>Max</td>
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<td>776,950</td>
<td>677,840</td>
<td>578,730</td>
<td>290,190</td>
</tr>
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<td>St.Dev</td>
<td>281,280</td>
<td>258,030</td>
<td>235,290</td>
<td>213,230</td>
<td>192,060</td>
<td>125,640</td>
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<td>0</td>
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<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Longline:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
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<td>201,350</td>
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<td></td>
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<tr>
<td><strong>Trap:</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
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<td>349,560</td>
<td>306,460</td>
<td>263,360</td>
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<td>Min</td>
<td>74,241</td>
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<td>47,048</td>
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<tr>
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<td></td>
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<td>Mean</td>
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<td>103,160</td>
<td>89,670</td>
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<td>164,580</td>
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Table 6.2: Predicted 1990 Profits of Fishers at Different Levels of Rent Capture with a Profit Charge using a Normalised Quadratic and Translog Profit Functions ($)

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<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>90%</th>
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<tr>
<td>Trap:</td>
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<tr>
<td>Mean</td>
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<td>182,950</td>
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<td>0</td>
<td>0</td>
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<td>Longline:</td>
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</tr>
<tr>
<td>Mean</td>
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Table 6.4: Predicted 1990 Profits of Fishers at Different Levels of Rent Capture with an *Ad Valorem* royalty using a Normalised Quadratic and Translog Profit Functions ($)

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Table 6.5: Predicted 1990 Profits of Fishers at Different Levels of Rent Capture with a Lump Sum Charge using a Normalised Quadratic and Translog Profit Functions ($)

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Chapter 7

Summary and Conclusions

But the more I studied economic science, the smaller appeared the knowledge which I had of it, in proportion to the knowledge I needed; and now, at the end of nearly half a century of almost exclusive study of it, I am conscious of more ignorance of it than I was at the beginning of the study.


7.1 Summary of Contributions

The thesis addresses an important problem in natural resource economics, the capture of rent in rights based fisheries. In addressing the problem, the thesis provides a review of the classical and modern views of rent and uses the general literature to provide a context for definitions of various types of short run rent in a rights based fishery. In particular, the thesis separates the concept of management rent from a resource or scarcity rent and introduces the notion of a marginal quasi-rent in a fishery. The desirability of capturing the various types of rent is discussed in the context of the payment they represent to which factor of production.

To examine the issues of rent capture, an original theoretical model is developed. Such a framework has general applications for examining a variety of questions in rights based fisheries. In the model, it is assumed there are two types of fishers
who differ only with respect to their harvesting functions and who maximise the expected utility of economic profits. Using the model, the short-run quota equilibrium is compared to a first-best result where a resource owner is able to determine the number of fishers of each type, their catch, and the total harvest. Hitherto ignored differences between the first-best, short run, and long run outcomes are emphasised.

Using the conceptual framework the effect of uncertainty on the fishery is addressed under assumptions that fishers are risk averse. Given plausible assumptions with respect to the cost curves of fishers, it is shown that the short-run equilibrium for a given number of fishers without uncertainty and/or with risk neutral behaviour maximises the expected short-run rent in the fishery. In general, uncertainty and risk averse behaviour will reduce the expected short-run rent although a special case is found where the equilibrium with and without uncertainty are identical. Such a result is contrary to the accepted belief that a fixed producer price system is the only method of regulation that generates a first best optimum under price uncertainty. Reducing the uncertainty faced by all fishers is shown not to decrease and in general will increase the expected rent although changing the risk faced by some but not all fishers may increase or decrease the rent.

Applying the model to various methods of rent capture, general results are presented on the different effects of various rent capture schemes. Comparing the methods of rent capture, it is shown that if fishers face the same output price an *ad valorem* royalty charged on the quota-holdings of fishers is identical to a quota rental charge. Fishers with a higher average profit per unit of quota are also shown to pay proportionately more with a profit charge than a quota rental charge in comparison to fishers with a lower average profit per unit of quota.

Examining the methods of rent capture according to their effect upon the quota equilibrium, it is shown that both a quota transfer charge and lump sum charge are
capable of changing the Pareto efficient outcome. In the case of risk averse behaviour and uncertainty with respect to the output price, it is shown that the profit charge, net cash flow charge, and *ad valorem* royalty are capable of changing the short-run quota equilibrium. Such methods of rent capture, by reducing the uncertainty faced by fishers, are shown to actually increase the expected rent in the fishery but at the expense of reducing the expected utility of fishers. In comparison, a quota rental charge does not change the short-run quota equilibrium with or without uncertainty.

The thesis also presents for the first time an empirical analysis of the effects of rent capture in a rights based fishery. Prior to simulating the effects of rent capture, three different approaches for estimating the rent in the fishery in 1988 and 1990 are provided. Using predicted profits in 1990, the year ITQ management was first introduced into the fishery, the different methods of rent capture are analysed. Some of the theoretical results are confirmed in that vessels of one gear-type collectively have higher profits per quantity of fish harvested and correspondingly pay less with a quota rental charge than an equivalent profit charge. The simulations also show that fishers with the highest ratio of net cash flow to profits are one of the least favoured with respect to a net cash flow charge. An *ad valorem* royalty imposed on the actual output price received by fishers multiplied their landings is also shown to be quite different in its effect than a quota rental charge. Under such a royalty, fishers with a lower than average price for their product are shown to pay less rent than with an equivalent quota rental charge.

The effects of rent capture with respect to the quota equilibrium and efficiency of fishers are also examined empirically. In the given fishery, a lump sum charge is shown to be distortionary by favouring fishers with larger quota-holdings at the expense of smaller but not necessarily less profitable operations. A method is also proposed using the traded quota price and a defined rate of interest, to separate the
intra-marginal rents and expected resource rent.

7.2 Suggestions for Further Research

The conceptual framework of the thesis is used to present a number of important results. There exist, however, some useful additions to the work. In the thesis, the issue of uncertainty is examined only with respect to fluctuations in the output price. The analysis may be expanded by addressing fluctuations in the TAC, biomass, and input prices. The theoretical model may also be extended by explicitly examining the rent capture problem in a multi-species framework while retaining the assumption of heterogeneous fishers. This would provide an opportunity to examine interactions across fisheries and the effects of different charge rates on different species and the optimal output mix of fishers.

Another extension to the work that may also prove useful would be to model the expectations of fishers explicitly. In this manner, the effects of exogenous shocks on the fishery and the adjustment process may be analysed more effectively. The adjustment process and effects of rent capture may also be assessed by examining the fishers' problem with the use of stochastic dynamic programming. Such methods may also prove useful in explicitly modelling the investment of fishers under different rent capture schemes and the risk attitude of fishers.

In the empirical work, the predicted profits of fishers are derived without explicit reference to the uncertainty in the fishery. Incorporating estimates of fisher profits with uncertainty, possibly in a multi-period framework, may add richness to the results. It may also be useful to examine multi-species fisheries that are collectively managed with ITQ's. Such fisheries may prove useful in investigating the effects of rent capture across species and assessing the optimal behaviour of fishers.


Bibliography


Bibliography


Taking expression (3.17) and dividing the numerator and denominator by \((a1a2)\), where \(a1 = 2C + 2\xi_1^2b^2\beta_1\sigma_P^2\) and \(a2 = 2C + 2\xi_2^2b^2\beta_2\sigma_P^2\), the partial derivatives of the quota price with uncertainty and risk aversion are as follows:

\[
\frac{\partial \Gamma_t}{\partial \beta_1} = -\frac{TAC\left(\frac{2\xi_1^2Xb^2 r\sigma_P^2}{a1^2}\right)}{\left(\frac{X\xi_1^2b^2 r}{a1} + \frac{Y\xi_2^2b^2 r}{a2}\right)^2} < 0 \quad (A.1)
\]

\[
\frac{\partial \Gamma_t}{\partial \beta_2} = -\frac{TAC\left(\frac{2\xi_2^2Yb^2 r\sigma_P^2}{a2^2}\right)}{\left(\frac{X\xi_1^2b^2 r}{a1} + \frac{Y\xi_2^2b^2 r}{a2}\right)^2} < 0 \quad (A.2)
\]

\[
\frac{\partial \Gamma_t}{\partial C} = -\frac{TAC\left(\frac{2\xi_1^2Xb^2 r}{a1^2} + \frac{2\xi_2^2Yb^2 r}{a2^2}\right)}{\left(\frac{X\xi_1^2b^2 r}{a1} + \frac{Y\xi_2^2b^2 r}{a2}\right)^2} < 0 \quad (A.3)
\]

\[
\frac{\partial \Gamma_t}{\partial r} = \frac{TAC}{\left(\frac{X\xi_1^2b^2 r}{a1^2} + \frac{Y\xi_2^2b^2 r}{a2^2}\right)} - \frac{\bar{P}}{\bar{r}^2}
\]

\[= \frac{\Gamma_t}{r} < 0 \text{ if } \Gamma_t > 0 \quad (A.4)
\]

\[
\frac{\partial \Gamma_t}{\partial TAC} = -\frac{1}{\left(\frac{X\xi_1^2b^2 r}{a1} + \frac{Y\xi_2^2b^2 r}{a2}\right)} < 0 \quad (A.5)
\]
\[ \frac{\partial \Gamma_t}{\partial \sigma_p^2} = -\frac{TAC\left(\frac{2\xi_t^2 X_t b_t^2 r}{\sigma_1^2} + \frac{2\xi_t^2 Y_t b_t^2 r}{\sigma_2^2}\right)}{\left(\frac{X_t b_t^2 r}{\sigma_1^2} + \frac{Y_t b_t^2 r}{\sigma_2^2}\right)^2} < 0 \] (A.6)

\[ \frac{\partial \Gamma_t}{\partial \hat{P}} = \frac{1}{r} > 0 \] (A.7)

\[ \frac{\partial \Gamma_t}{\partial b} = \frac{TAC\left(\frac{4\xi_t^2 X_t b_t^2 r}{a_1^2} + \frac{4\xi_t^2 Y_t b_t^2 r}{a_2^2}\right)}{\left(\frac{X_t b_t^2 r}{a_1^2} + \frac{Y_t b_t^2 r}{a_2^2}\right)^2} > 0 \] (A.8)

\[ \frac{\partial \Gamma_t}{\partial X} = \frac{TAC\left(\xi_t^2 b_t^2 r\right)}{\left(\frac{X_t b_t^2 r}{a_1^2} + \frac{Y_t b_t^2 r}{a_2^2}\right)^2} > 0 \] (A.9)

\[ \frac{\partial \Gamma_t}{\partial Y} = \frac{TAC\left(\xi_t^2 b_t^2 r\right)}{\left(\frac{X_t b_t^2 r}{a_1^2} + \frac{Y_t b_t^2 r}{a_2^2}\right)^2} > 0 \] (A.10)

\[ \frac{\partial \Gamma_t}{\partial \xi_1} = \frac{TAC\left(\frac{4\xi_t^2 X_t b_t^2 r}{a_1^2}\right)}{\left(\frac{X_t b_t^2 r}{a_1^2} + \frac{Y_t b_t^2 r}{a_2^2}\right)^2} > 0 \] (A.11)

\[ \frac{\partial \Gamma_t}{\partial \xi_2} = \frac{TAC\left(\frac{4\xi_t^2 Y_t b_t^2 r}{a_2^2}\right)}{\left(\frac{X_t b_t^2 r}{a_1^2} + \frac{Y_t b_t^2 r}{a_2^2}\right)^2} > 0 \] (A.12)
Appendix B

Description of the Data

The data used to estimate the two variable profit functions comes from a number of sources. A costs and earnings survey (CES) undertaken by the Department of Fisheries and Oceans (DFO) for the year 1988 supplied information on total expenditures on fuel and labour, and total revenue from sablefish and other species. The data collected was obtained from 28 of the possible 46 fishers that actively fished for sablefish in 1988. In total, 17 out of 25 longline vessel owners and 11 out of a possible 21 trap vessel owners were interviewed. In addition, catch statistics data including information on the quantity of fish landed by species and the price received by fishers was available for all fishers and for all years up to and including 1990. This information is collected separately by the DFO for all licensed fishing vessels in British Columbia. Diesel marine fuel prices were obtained from Chevron Canada by different homeports of fishers for the years 1988 and 1990. Information on the registered tonnage of vessels and length of vessels was obtained from the Vancouver Ship Registry. Information on the bank rate on prime business loans was obtained from various issues of the Bank of Canada Review while data on weekly unemployment benefits, average weekly earnings, and unemployment rates by regions were obtained from various publications available from Statistics Canada.

Detailed information of the data sources and data generation used to estimate the profit functions is listed below.
Sablefish Output and Price

Using DFO catch statistics for 1988 and 1990, the total value and round weight of sablefish landings by vessel were obtained. Using the 1988 data and for only those vessels included in the CES, a sablefish price and output supply series was derived. For the normalised quadratic function, a price index was obtained such that the first observation was set equal to one. This procedure was followed for all other price variables. Dividing the total revenue from sablefish by this price index, an implicit quantity index was derived. To predict sablefish profits in 1990, the price of sablefish per vessel was obtained from 1990 catch statistics. In the case of the normalised quadratic function, this price was indexed in the same fashion as for 1988 using the same base price.

Other Species Output and Price

Catch statistics from the DFO were also used to generate an aggregate price series and quantity variable for species caught other than sablefish. This aggregation across all species other than sablefish was performed for all 28 vessels in the CES. The aggregation involved calculating a base quantity and base price over all the relevant vessels for each species. The base price being the mean price over all the sample of vessels and the base quantity being the total catch in kg over all vessels. Using these base values, a Paasche and a Laspeyres price index was calculated for each vessel. Taking a geometric average of the two indexes, a Fisher price index per vessel for species other than sablefish was derived [Diewert (1989)]. Using the Fisher price index per vessel, an implicit quantity index was obtained by dividing the total revenue per vessel from species other than sablefish by the price index. A similar procedure was followed for 1990 using the same base price and quantity values for 1988 but with
price and quantity data for each vessel that fished in 1990.

**Fuel Price and Input Demand**

To determine the fuel prices paid by fishers it is first necessary to know their homeports. Using vessel and homeport information supplied directly by the DFO, each vessel was assigned a particular location where it was assumed that purchases for provisions and fuel took place. The homeports of the vessels included in the CES are as follows.

1. Ucleulet
2. Vancouver
3. Steveston
4. Victoria
5. Sooke
6. Sidney
7. Gibsons/Sechelt
8. Port Hardy

Marine diesel fuel prices for each of the homeports of fishers were obtained from Chevron Canada for each month of 1988. Vessels were then assigned the fuel price existing at the time they were fishing for sablefish that year. Fuel prices for 1990 with the homeports of vessels that fished for sablefish in that year were also supplied by Chevron Canada. A monthly average of the fuel price existing over that period was used to assign a fuel price to each vessel. In the case of the normalised quadratic
function, a fuel price index was derived from the price series such that the first observation was set equal to unity. A quantity of fuel per vessel was obtained by dividing the fuel price or fuel price index assigned per vessel into the total fuel expenditures per vessel.

**Opportunity Wage and Labour Services**

It is standard practice in fishing to pay the crew on a share basis. As a result wage expenditures may be dependent on the returns and profits in the fishery. To avoid a simultaneity problem in estimation it is common practice to estimate an opportunity cost wage for a vessel.

Following Dupont (1988: 218-221) the vessels used in the estimation were assigned a region according to the location of their homeports. These regions correspond to areas used by Statistics Canada and for coastal areas include:

1. Metropolitan Vancouver
2. Metropolitan Victoria
3. Vancouver Island other than Victoria
4. Lower Mainland
5. Prince Rupert

Using the unemployment rate for the relevant region, an industrial aggregate of an average weekly wage in B.C, and an average weekly unemployment benefit one may calculate an expected average weekly earnings per person per vessel (Dupont, 1988: 218):

\[
EAWE = (1 - U) \times AWE + U \times AWUIB
\]

(B.1)
where $AWE$ is average weekly earnings in the industrial aggregate for B.C. from Canada Employment, Earnings and Hours, $U$ is the regional unemployment rate from B.C. Labour Characteristics by Economic Region and Metropolitan Area, and $AWUIB$ is the average weekly unemployment benefit from Statistical Report on the Operation of the Unemployment Insurance Act, Table 6.

This measure of expected average weekly earnings is the opportunity cost wage faced by each vessel. It reflects both the alternative wage available to crew members and the difficulty in finding alternative employment and was calculated for each vessel for 1988 and 1990. Indexing the opportunity cost wage such that the first observation was unity, a measure of the quantity of labour was derived by dividing the index into the total labour expenditures per vessel including food and bait.

To obtain an estimate of the total opportunity cost wage from fishing from sablefish in 1988, data was obtained on the number of crew used in fishing for sablefish from the CES and the number of fishing days per vessel. Calculating the number of weeks worked by the crew in total and multiplying by the EAWE one obtains an opportunity cost wage for the crew. Assuming one skipper per vessel and including the time spent on repairs and maintenance as given in the CES, an opportunity cost wage for the skipper may also be determined using the same EAWE. Aggregating the two costs, one obtains a measure of the total opportunity cost wage per vessel from sablefish.