Individual Vessel Quotas and Income Effects

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As a means of solving the common property problem, fisheries regulators are currently looking into replacing regulatory programmes that do not prevent rent dissipation (reduction in economic rent associated with overharvesting), such as limited entry (Rettig 1984; Dupont 1990), with individual vessel quotas (Clark et al. 1988; Geen and Nayar 1988). While the introduction of vessel quotas may promote the efficient use of resources and lead to increased rent from the fishery, there has been little economic analysis of the implications of such a policy for the income distributions of fishermen. Indeed, the consequences may be devastating for some individuals since it is widely accepted that rationalization inevitably means job losses, perhaps substantial (Scott 1979; Crutchfield 1979).

In a recent paper, Dupont and Phipps (1991) investigated the distributional implications of the imposition of a royalty tax and a change in catch distribution among competing user groups for the British Columbia commercial salmon fishery. They found that an empirical evaluation of distributional gains and losses from alternatives to the status quo (limited entry with input restrictions per vessel) does

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not always result in a socially justifiable outcome. The purposes of this article are twofold. First, it modifies the methodology in Dupont and Phipps (1991) in order to examine how output controls in the form of individual vessel quotas compare efficiency-wise with royalty taxes and input controls on the fishing firm. Second, this article extends the distributional analysis by considering an additional method of evaluating gains to one individual and losses to another.

To examine the distributional benefits and costs of alternative fisheries regulations, we start with a model of the harvest technology. This is used to estimate three important functional relationships that establish base case results according to the status quo values of several key variables. By changing the values of certain parameters in the estimated functions, we can simulate the impact of alternative forms of fisheries regulations on the key variables. A comparison of pre- and postregulatory change values for these key variables give comparative statics-type results. The key variables of interest in this article are: aggregate fishery rent, total fishery employment, and fishermen's incomes. Changes in these variables will quantify the distributional benefits (in the form of increased resource rent) and costs (in the form of lost income for fishermen forced to exit the fishery through rationalization) of different regulatory proposals.

The next step evaluates these costs and benefits in order to examine the distributional consequences of the individual vessel quota. This is accomplished by developing measures that consider the rent gains, distribution of the rent gains, and employment losses assuming alternately an utilitarian viewpoint, a Rawlsian viewpoint, and an entitlement viewpoint. By examining these various ethical viewpoints, we address the current interest in achieving fairness in the use of natural resources (Davis and Thiessen 1986).

The rest of this article is organized in the following manner. The first section describes the British Columbia commercial salmon fishery, and the second section uses this information to model and estimate the fish harvest technologies of the four competing vessel types in the fishery. Section three then discusses in detail the methodology used to evaluate the welfare implications of alternative regulatory schemes. The results appear in the fourth section, and the fifth section concludes with a discussion of policy implications.

The British Columbia Commercial Salmon Fishery

The commercial salmon fishery in British Columbia is the province's most lucrative and important fishery for employment and catch. In 1987, salmon accounted for almost 40 percent of the total quantity of

fish landed and more than 50 percent of the total landed value (British Columbia Ministry of the Environment, Marine Resources Branch 1988). Four types of vessels compete for Pacific Coast salmon species. These vessels have either nets alone (seine and gillnet), lines alone (troll), or a combination of nets and lines (gillnet-troll). In addition, each vessel owner uses different combinations of labour, fuel, equipment, and capital (vessel) inputs. The vessels range in size from seine vessels using from four to seven persons (the largest) to gillnet vessels, often a one-person operation (the smallest), with troll and gillnet-troll in between.

The fishery is currently regulated with a limited-entry licensing programme that effectively sets an upper bound on the number of participating vessels. This programme was adopted in 1969 and proved so ineffective at preventing "capital-stuffing" (a form of rent-dissipating behaviour in which more capital than is strictly necessary is devoted to capturing a given quantity of fish—see Rettig 1984) that tonnage restrictions were imposed on each vessel in 1972. These input restrictions, however, have not been particularly successful in preventing rent dissipation in this fishery (Pearse 1982; Dupont 1990). In addition to input controls, the regulator restricts the number of fishing days (through area openings and closings) to ensure stock preservation and each year determines the total allowable catch for the fishery as a whole.

A Model of Fish Harvest Technology

This section describes the behavioural model used to obtain base case estimates and subsequent simulation values for the key variables of British Columbia salmon fishery rent, employment, and fishing incomes. To evaluate the impact of output restrictions (quotas) on each vessel, we began with a model that postulates the cost-minimizing behaviour of a representative competitive fishing firm. This is in contrast to our earlier use of a restricted profit function model (in which output was a choice variable of the fishing firm) to examine the impacts of royalty taxes on fishing behaviour (Dupont and Phipps 1991). In that model, we allowed for output responses to price changes because a royalty tax effectively reduces the after-tax price to the fisherman. In the model presented in this article, the emphasis is on the reaction of the fisherman to an output restriction in the form of a catch quota.

Fish harvesting can be represented by a production function that describes how the variable inputs at the disposal of the fishing firm (for example, labour, fuel, and gear) can be combined to produce output (landed catch). According to duality theory, a function that is dual to the primal production function (Brown and Christensen 1979) can be used to estimate the harvest technology. In this context, it is reasonable to assume that the fishing firm wishes to minimize the seasonal cost of taking a given catch, subject to exogenous variable input prices and to constraints on its behaviour. These constraints include restrictions governing the size of the vessel (tonnage) and the number of fishing days permitted by the regulator, the seasonal abundance of fish as determined by nature, and the seasonal catch quota.

The dual function we adopt is a restricted cost function. Its arguments include the prices of variable inputs (labour, fuel, and gear) and the quantities of restricted or fixed inputs (stock abundance, tonnage, fishing days, and the catch quota). We use a variant of the normalized quadratic restricted profit function (Dupont and Phipps 1991) to represent restricted cost. This particular flexible functional form permits the researcher to impose concavity on input prices (Varian 1985), a property of a well-behaved cost function.[1]

Equation (1) specifies the normalized quadratic restricted cost function with three variable input prices, three restricted inputs, and a single catch quota.

$$C^R(P, Z) = 1/2 \sum_{j=1}^{4} \alpha_j Z_j \sum_{i=1}^{3} \sum_{k=1}^{3} a_{ik} \frac{P_i P_k}{P_F} + 1/2 \sum_{i=1}^{3} \beta_i P_i \sum_{h=1}^{4} \sum_{j=1}^{4} b_{hj} \frac{Z_h Z_j}{Z_s} + \sum_{i=1}^{3} \sum_{j=1}^{4} c_{ij} P_i Z_j + \sum_{i=1}^{3} \beta_i P_i \sum_{j=1}^{4} b_j \frac{Z_j}{Z_s} + 1/2 \sum_{i=1}^{3} b_0 \beta_i \frac{P_i}{Z_s} + \sum_{i=1}^{3} c_i P_i \qquad (1)$$

The subscripts i,k = 1,2,3 imply indexing over prices in the order of P_F, P_L, P_G, and j,h = 1,2,3,4 imply indexing over three fixed inputs and a single catch quota in the order of Z_S, Z_T, Z_D, and Z_Y. The function is normalized by the arbitrary choice of one input price and one restricted factor. Numeraires are P_F (price of fuel input) and Z_S (fish abundance). Subsequent analysis verifies that the choice of numeraire makes little difference to parameter estimates. Parameters to be estimated are a_{ik}, b_{hj}, c_{ij}, b_j, b_0, and c_i. Diewert and Wales (1987) assert that parameters α_j (j = 1, . . . ,M) and $ß_i$ (i = 1, . . . ,N) may be arbitrarily preset by the researcher without loss of flexibility. Diewert (1986) assigns the value $1/Z'_j$ to α_j, where Z'_j is the fixed quantity vector for the first observation. Likewise, $ß_i$ may be set equal to $1/P'_i$. This convention is adopted in this article.

1. Flexibility in the context of dual functions refers to the ability to distinguish different elasticities of substitution between input pairs. A Cobb-Douglas function is not flexible because it imposes a constant elasticity of substitution between each input pair.

The data include a cross-sectional survey of Pacific Coast fishermen conducted by the Department of Fisheries and Oceans for 1982, which gives expenditure information by vessel for a variety of categories, and 1982 sales, which supplements the first by providing revenue and output information. For each vessel, a complete data set includes quantities and prices of output and three variable inputs—labour, fuel, and gear—as well as levels of three fixed inputs—tonnage, fishing days, and fish stock abundance.

A Divisia index for aggregate output price is generated using data on prices for five species of salmon. It takes into account the different prices paid for the five species of salmon and produces a weighted average composite price. The implicit aggregate quantity index is obtained by dividing total fishing receipts by the aggregate price index (insufficient data preclude estimation of a multi-output model). An opportunity cost wage is constructed for labour (Squires 1987) using average weekly earnings in an industrial composite category for the province of British Columbia and five important regional centres (Statistics Canada 1982a). Each vessel is assigned to a region based on its home port, obtained from the survey. An expected opportunity cost weekly wage is constructed to take into account the possibility of less than full employment. Data on unemployment rates were taken from British Columbia's *Basic Labour Force Characteristics by Economic Region and Metropolitan Area*, found in the on-line CANSIM data base maintained by Statistics Canada. The number of weeks fished by each vessel is used to construct an opportunity cost for the salmon fishing season.

Fuel prices were obtained from Esso Canada for gasoline and diesel products sold in 11 centres. Fuel expenditures were divided by relevant fuel prices to determine the quantity of fuel input. The gear input consists of nets, lines, traps, and other items used by each vessel. Gear is taken to be a malleable capital good whose services are not entirely exhausted in one year. For each type of gear a stock is constructed. It is assumed that each unit of gear, no matter its age, provides a constant flow of services because of repairs and maintenance received. A rental cost of gear is calculated for each type using a modified version of the capital services price formulated by Jorgenson (1963). The modification allows inclusion of the cost of repairs and maintenance (Schworm 1977). A Divisia gear price index is constructed using quantity and unit rental price data. This incorporates all prices paid for the various types of gear. A capital services price for tonnage (used in calculating fishery rent) is also generated by using Jorgenson's equation.

Various sources were used for data on fixed factors: tonnage, Department of Fisheries and Oceans license records; number of fishing days for each vessel, 1982 survey of Pacific Coast fishermen; and stock abundance, from data on catch and escapement in each of 29 management areas. For each vessel, stock encountered is calculated as the relative abundance in each fishing area weighted by the number of weeks the vessel fished in that area. Stock in each area is an aggregate of the five species of salmon found along the Pacific Coast.

Instead of estimating the restricted cost function in equation (1), it is more convenient to estimate a system of three equations describing the variable inputs demanded as functions of prices and fixed quantities. These equations are obtained by applying Shephard's lemma to equation (1), and they contain all the parameters. Since there are fewer parameters in each of the input demand equations, there is less likelihood of multicollinearity problems, which the researcher might encounter when estimating the restricted cost function. The input demand equations are as follows:

$$\frac{\delta C^R(P,Z)}{\delta P_F} = X_F^*(P_F, P_L, P_G; Z_S, Z_T, Z_D, Z_Y)$$

$$= -1/2 \sum_{j=1}^{4} \alpha_j Z_j \sum_{i=1}^{3}\sum_{k=1}^{3} a_{ik} \frac{P_i P_k}{P_F^2} + 1/2\, \beta_F \sum_{h=1}^{4}\sum_{j=1}^{4} b_{hj} \frac{Z_h Z_j}{Z_s}$$

$$+ \sum_{j=1}^{4} c_{Fj} P_i Z_j + \beta_F \sum_{j=1}^{4} b_j \frac{Z_j}{Z_s} + 1/2 \frac{b_0 \beta_F}{Z_s} + c_F \qquad (2)$$

$$\frac{\delta C^R(P,Z)}{\delta P_i} = X_i^*(P_F, P_L, P_G; Z_S, Z_T, Z_D, Z_Y)$$

$$= \sum_{j=1}^{4} \alpha_j Z_j \sum_{k=1}^{3} a_{ik} \frac{P_i P_k}{P_F} + 1/2\, \beta_i \sum_{h=1}^{4}\sum_{j=1}^{4} b_{hj} \frac{Z_h Z_j}{Z_s}$$

$$+ \sum_{j=1}^{4} c_{ij} P_i Z_j + \beta_i \sum_{j=1}^{4} b_j \frac{Z_j}{Z_s} + 1/2 \frac{b_0 \beta_i}{Z_s} + c_i \qquad (3)$$

where X_i = L,G. Such a linear system can be estimated using the iterative technique of Zellner (1962) for "seemingly unrelated regressions" (SUR) for each of the four vessel types used in the British Columbia salmon fishery: seine (21), gillnet (80), troll (84), and gillnet-troll (60).[2]

The system of equations (2)-(3) does not impose concavity in prices. One can, however, verify whether concavity in prices is accepted by checking that the eigenvalues of the Hessian matrix are all nonpositive. If they are not, concavity can be subsequently imposed. This is done by replacing matrix A, formed by the a_{ik} parameters, with the

2. The number in parentheses is the number of observations corresponding to each vessel type. As noted earlier, most gillnet vessels are owner-operated. Thus, in this sample we treat labour as a fixed input, and we estimate only two variable input demand equations—one for fuel and one for gear.

product of a matrix D and its transpose D^T. Thus, $A = DD^T$, where the D matrix is a lower triangular matrix with zeroes in its first column. When this substitution takes place, the normalized quadratic restricted cost function becomes non-linear and requires a non-linear maximum likelihood estimation technique (Dupont and Phipps 1991).

Estimation begins with the SUR parameter estimates. After they are checked for acceptance of concavity in prices, concavity is imposed on seine and gillnet-troll samples and accepted by troll and gillnet samples. Tables 1-4 give parameter values and their standard errors for the estimated restricted cost functions.

The estimated input demand equations are used to predict optimal quantities of variable inputs and associated rent levels, as well as fishing incomes, for different levels of individual vessel quotas. Rent is defined as the difference between total revenue (calculated as the product of the aggregate output price and the catch quota) and predicted cost. The restricted cost function gives predicted total variable cost only. We add to this an estimate of total fixed cost by multiplying total vessel tonnage by the capital service price of one ton. Because information on individual fishing incomes is not available, we simulate them with the product of the weekly opportunity cost for each vessel's home port and the number of weeks fished. These estimates compare favourably with estimates of the average fishing income in British Columbia for 1982 as calculated from federal income tax return statistics (Revenue Canada, Taxation Division 1984).

Methodology for Evaluating the Distributional Implications of Quota Systems

Economists traditionally have avoided assessing the distributional consequences of policy proposals. Yet few policies are able to increase the well-being of some people without simultaneously reducing the well-being of others. In other words, few policy proposals can be judged strictly on the basis of the Pareto Principle (Boadway and Bruce 1984). Thus, choosing a policy requires a subjective evaluation of distributional outcomes.

The quota allocation proposals analyzed in this article are an excellent example of this dilemma. Implementation of either proposal means that some fishermen will suffer income losses. At the same time, rent gains obtained through regulation will benefit some individuals, depending on how the rent gains are distributed. Sensible fisheries regulatory choices thus require an evaluation of the distributional consequences of the policies under consideration. To avoid imposing our own values, however, we conduct this evaluation from more than one

TABLE 1 Cost Function Parameter Estimates for Seine Vessels

Variable	Coefficient	Standard Error	Variable	Coefficient	Standard Error
d_1	-0.108[a]	0.037	c_{FT}	-4.153[a]	1.923
d_2	-0.291[a]	0.077	c_{FD}	1.011	1.000
d_3	-0.659×10^{-8}	0.397×10^{-7}	c_{FY}	1.960[b]	0.720
b_{YY}	0.008	0.201	c_F	-9.411[a]	2.916
b_{YT}	0.825[b]	0.464	c_{LS}	3.265[a]	0.627
b_{YD}	-0.833[a]	0.246	c_{LT}	-6.483[a]	0.892
b_{TT}	-8.416[a]	1.809	c_{LD}	0.087	0.496
b_{TD}	-2.263	1.784	c_{LY}	2.039[a]	0.343
b_{DD}	2.470[a]	0.490	c_L	-6.760[a]	1.748
b_0	12.305[a]	2.337	c_{GS}	-12.498[b]	7.469
b_Y	-2.496[a]	0.565	c_{GT}	-21.707[b]	11.223
b_T	13.286[a]	2.210	c_{GD}	9.780	6.120
b_D	-0.720	-0.723	c_{GY}	-4.546	4.679
c_{FS}	3.801[a]	1.333	c_G	29.196[b]	14.347

Note: The d coefficients are related to the a_{ik} parameters as follows: $d_1^2 = a_{FF}$, $d_1 d_2 = a_{FG}$, and $d_2^2 + d_3^2 = a_{GG}$.

a. Significantly different from zero at the 5 percent level.

b. Significantly different from zero at the 10 percent level.

TABLE 2 Cost Function Parameter Estimates for Gillnet Vessels

Variable	Coefficient	Standard Error	Variable	Coefficient	Standard Error
a_{22}	-0.491×10^{-3}[b]	0.299×10^{-3}	c_{FS}	-0.145[b]	0.068
b_{YY}	-0.047	0.082	c_{FT}	-0.095	0.138
b_{YT}	0.116	0.122	c_{FD}	0.128[a]	0.043
b_{YD}	-0.087[a]	0.028	c_{FL}	-0.351[b]	0.186
b_{YL}	-0.039	0.149	c_{FY}	0.223[b]	0.121
b_{TT}	-0.030	0.344	c_{GS}	-0.034	0.064
b_{TD}	-0.053	0.076	c_{GT}	-0.164	0.133
b_{TL}	-0.212	0.384	c_{GD}	0.053	0.041
b_{DD}	0.024	0.025	c_{GL}	-0.382[b]	0.180
b_{DL}	-0.016	0.091	c_{GY}	0.193[b]	0.119
b_{LL}	-0.348	0.313			

a. Significantly different from zero at the 5 percent level.

b. Significantly different from zero at the 10 percent level.

TABLE 3 Cost Function Parameter Estimates for Troll Vessels

Variable	Coefficient	Standard Error	Variable	Coefficient	Standard Error
a_{22}	-0.015[b]	0.010	c_{FT}	0.319	0.481
a_{23}	0.001	0.143×10^{-2}	c_{FD}	-0.162	0.362
a_{33}	-0.402×10^{-4}	0.245×10^{-3}	c_{FY}	0.120[b]	0.053
b_{YY}	0.003	0.006	c_F	0.381	0.552
b_{YT}	0.033	0.031	c_{LS}	0.537[b]	0.269
b_{YD}	-0.032	0.042	c_{LT}	-0.545	0.479
b_{TT}	-0.125	0.160	c_{LD}	-0.109	0.357
b_{TD}	0.234	0.173	c_{LY}	0.009	0.053
b_{DD}	0.273	0.275	c_L	1.587[a]	0.547
b_0	0.191	0.399	c_{GS}	-0.221	1.214
b_Y	-0.026	0.043	c_{GT}	-1.520	1.243
b_T	-0.067	0.262	c_{GD}	-0.259	1.351
b_D	-0.376[b]	0.269	c_{GY}	0.216	0.194
c_{FS}	-0.196	0.275	c_G	1.942	1.622

a. Significantly different from zero at the 5 percent level.

b. Significantly different from zero at the 10 percent level.

TABLE 4 Cost Function Parameter Estimates for Gillnet-Troll Vessels

Variable	Coefficient	Standard Error	Variable	Coefficient	Standard Error
d_1	0.124[b]	0.060	c_{FT}	1.508[b]	0.576
d_2	0.014	0.018	c_{FD}	0.253[a]	0.088
d_3	0.467×10^{-8}	0.490×10^{-7}	c_{FY}	0.057	0.071
b_{YY}	-0.020[b]	0.013	c_F	-1.533[b]	0.657
b_{YT}	-0.136	0.166	c_{LS}	0.032	0.164
b_{YD}	0.002	0.017	c_{LT}	1.953[a]	0.566
b_{TT}	3.800[a]	1.479	c_{LD}	0.299[a]	0.085
b_{TD}	-0.473[b]	0.201	c_{LY}	0.031	0.071
b_{DD}	-0.010	0.052	c_L	-1.197[b]	0.647
b_0	4.561[b]	1.745	c_{GS}	-38.586	25.712
b_Y	0.296[b]	0.166	c_{GT}	110.110[b]	66.007
b_T	-4.287[a]	1.489	c_{GD}	1.133	11.778
b_D	0.367[b]	0.224	c_{GY}	-8.360	6.515
c_{FS}	0.029	0.175	c_G	3.921	72.116

Note: The d coefficients are related to the a_{ik} parameters as follows: $d_1^2 = a_{FF}$, $d_1 d_2 = a_{FG}$, and $d_2^2 + d_3^2 = a_{GG}$.

a. Significantly different from zero at the 5 percent level.

b. Significantly different from zero at the 10 percent level.

point of view. We effectively conduct a sensitivity analysis over alternative ways of viewing the equity issues involved.[3]

Utilitarian Methodology

A utilitarian approach has often been adopted by economists interested in policy evaluation. With this approach, alternative policy proposals are evaluated in terms of their ultimate impact on the level of well-being in society. A generalized utilitarian approach (Feldstein 1973; Boadway and Bruce 1984; Dupont and Phipps 1991; Phipps 1991) evaluates proposals in terms of their final impact on the overall distribution of well-being in society, incorporating potentially different weights for low- versus high-income individuals.

To evaluate fisheries regulations from a generalized utilitarian perspective, we take the relevant population to be that of British Columbia.[4] Thus, it is consistent with this approach to assume that the entire population of British Columbia owns the salmon resource and is therefore entitled to any rent gains obtained through regulation. To assess the distributional implications of the rent gains generated by the two alternative proposals, we simulate the distribution of rent gains in equal shares to each member of the population of the province. (While it would, of course, be feasible to consider giving lower-income individuals larger-than-average shares of the rent, we know that any scheme that is welfare-improving with the equal-shares distribution will also be welfare-improving with a distribution scheme that weights low-income individuals more heavily.) Since all fishermen (including those who will lose their jobs through rationalization) are members of the relevant population, each will receive his or her share of the rent.

The losses resulting from the regulatory proposals under consideration are those of income by the fishermen no longer able to obtain employment in the fishery. Whether these losses will outweigh the benefits to be obtained through the distribution of rent shares will depend not only on the position of the fishermen in the provincial income distribution but also on the relative weights attached to gains or losses experienced by low- versus high-income individuals. All of

3. Although many perspectives other than the ones adopted here could be employed, we believe that our choices are reasonable ways of viewing the issues involved in fisheries regulation. Our point, however, is to illustrate a systematic approach to distributional questions rather than to draw policy conclusions. Thus, the choice of a particular ethical perspective is not critical.
4. Although we could take only the population of fishermen as the relevant population, this is less consistent with other applications of the utilitarian methodology. Moreover, we pay more specific attention to the population of fishermen with our third methodology.

this may be summarized through the following generalized utilitarian welfare evaluation measure:[5]

$$U = \{1/n(\sum_{i=1}^{n} y_i^r)\}^{1/r}, \qquad \text{if } 0 < r \leq 1 \qquad (4)$$
$$= \Pi_{i=1}^{n} y_i, \qquad \text{if } r = 0$$

In equation (4), n is the population of British Columbia; y is the income of individual i; and r is a parameter less than or equal to one. The parameter r can be interpreted as the evaluator's attitude toward inequality in the distribution of income (or well-being). If r = 1, the utilitarian measure is simply mean income in British Columbia. Equal weight is placed on all incomes, regardless of their level. If r is less than one, the greater weight is placed on lower incomes in the calculation of the mean.

A numerical example may help illustrate. Suppose the distribution of income in Economy A is {$5,000; $5,000; $5,000; $5,000; $100,000} and that of Economy B is {$24,000; $24,000; $24,000; $24,000; $24,000}. Calculating the generalized utilitarian measure with r = 1 in either five-person economy (A or B) yields U = $24,000—that is, the mean income in each economy is $24,000. But if r = - 5, then U = $5,230 in Economy A and U = $24,000 in Economy B. When there is inequality in the distribution of income, reducing the value of the inequality-aversion parameter, r, allows the evaluator to attach extra weight to income gains or losses experienced by those at the bottom of the income distribution.

For implementation, the relevant population is taken to be all income-receiving individuals 15 years and older living in British Columbia in 1982 (n = 1,921,000). Using income distribution figures from Statistics Canada (1982b), appropriate numbers of individuals are assigned the mean income of each provincial income cell. Incomes of fishermen under the current limited entry programme are used to determine their status quo position so that the income cell to which each fisherman belongs can be determined. Since we only have the total employment costs for any vessel, each crew member is assumed to earn an income equal to the average for that vessel. Lack of better data restricts us to these assumptions, but this analysis could be extended to allow for different incomes for each fisherman on a vessel if better information on fishing incomes were available. It could well be that the worst-off fisherman is more likely to be harmed by rationalization than the mean fisherman.

5. Note that, given the data limitations, individual income is the best available proxy for measuring individual well-being and that, moreover, we have no information on the incomes or characteristics of the households in which fishermen live.

The utilitarian policy evaluation measure for the base case is then calculated by assigning each non-fisherman the mean income of his or her income cell and each fisherman his or her simulated income. For subsequent regulatory schemes, the incomes of non-fishermen change only if fishery rents change and are distributed to the population of British Columbia. As citizens of the province, fishermen will receive a share of any rents distributed. But they also may be directly affected by the loss of a job. Whether the final consequence of these income gains and losses is an improvement in the overall distribution of income in the province is assessed through the utilitarian measure. Results will, of course, be extremely sensitive to the evaluator's attitude toward income inequality as well as to the position of fishermen in the provincial income distribution.

Rawlsian Methodology

Economists also have shown an interest in the ideas of John Rawls (1971). From a Rawlsian perspective, the most desirable regulatory policy is the one that most benefits the worst-off group. Rawls suggests that policies be chosen so as to maximize the well-being of the least well-off according to an index of "primary social goods", which may be approximated by net income, including transfers. Of course, "primary social goods" were intended to include rights, liberties, powers, opportunities, self-respect, income, and wealth. Rawls's suggested approximation is obviously extremely crude, but it has the merit of being operational.

To focus attention on the group worst-off in terms of income, the income distribution described in the previous section is censored at the poverty line ($5,949 in 1981-82, using the Statistics Canada low-income cutoff for a single individual living in a rural area). Thus, individuals with incomes above the poverty level are assigned poverty-level income; individuals with incomes less than poverty level are assigned their actual incomes.

The Rawlsian measure is then calculated from this censored income distribution. The measure is given by

$$R = \{\frac{n^R}{n}(y^P)^r + \frac{n^P}{n}(\varepsilon^P)^r\}^{1/r} \tag{5}$$

where again $r \leq 1$. In this equation, n^R is the number of "rich" individuals; n^P is the number of "poor" individuals; n is the total population of British Columbia; y^P is the poverty income level ($5,949); and ε^P, the

equally-distributed-equivalent income for the population of poor individual,[6] is defined by

$$\varepsilon^P = \{\frac{1}{n^P}(\sum_{i=1}^{n^P} y_i^r)\}^{1/r}, \quad \text{if } 0 < r \leq 1 \tag{6}$$

$$= \Pi_{i=1}^{n^P} \frac{y_i^r}{n^P}, \quad \text{if } r = 0$$

Thus, the Rawlsian measure assumes a form similar to that of the utilitarian measure with two important differences. First, a censored income distribution rather than the full distribution of income in British Columbia is employed, meaning that each individual is counted but that incomes above the poverty level are only counted as poverty level. Second, sensitivity to the distribution of income among poor individuals is achieved by calculating an equally-distributed-equivalent income for the poor population. This Rawlsian-style welfare evaluation measure is thus sensitive to the distribution of income between the poor and non-poor groups as well as to the distribution of income among the poor. Different levels of aversion to inequality can once again be incorporated by varying the parameter r.

Although the Rawlsian approach focuses attention on low-income individuals in British Columbia, we simulate the distributional benefits of the fisheries regulatory proposals as for the utilitarian evaluation (because we have never heard the argument that the poor of the province are entitled to the rent from the salmon fishery). As we argued earlier, it would be possible to divide the rent generated just among the poor population. Any proposal, however, that is welfare-improving under the equal-shares scheme also would clearly be welfare-improving if all rent gains were distributed to the poor.

Distributional losses are measured as income losses by fishermen who lose their jobs in the fishery, thereby placing them below the poverty level. From the Rawlsian perspective, an income loss that leaves an individual with more than poverty-level income would not be relevant.

Entitlement Methodology

Both the utilitarian and the Rawlsian measures are end-state approaches to policy evaluation. An alternative methodology is to select the regulatory proposal with the most equitable procedures. From this perspective, a policy yielding an improvement in the overall distribu-

6. Atkinson (1970) defined an equally-distributed-equivalent (ede) income as the level of income that, if distributed equally to all members of the population, would yield the same level of social welfare as that of the actual (unequal) population. This ede income will depend on the choice of a value for the inequality-aversion parameter, r.

tion of income achieved at the expense of a small number of individuals would not be fair. A procedural focus is an entirely different way of deciding what is equitable, although it appears to be an important objective for fisheries regulators (Pearse 1982).

To evaluate alternative regulatory schemes using this approach, it is necessary to change the focus from the entire population of British Columbia to the population of fishermen since it is fishermen who are directly affected by the policy proposals under consideration. It also seems reasonable to change the assumption about entitlement to the fishery resource. Fishermen who currently hold a license permitting them to catch salmon would argue that it constitutes a right to fish and an entitlement to an income from the fish resource. Our third evaluation methodology accepts this premise and uses status quo fishing incomes as the reference from which to judge the procedural fairness of alternative regulatory proposals.

This change of assumption about entitlement to resource rents suggests that an equal-shares distribution of rent gains is no longer appropriate. Instead, we simulate a scheme whereby rent gains are first used to compensate fishermen who exit the fishery because of the policy change. This is surely a minimum condition for procedural fairness.[7] Any surplus rent can then be divided among fishermen, both those who have been excluded and those who continue to fish. From the entitlement perspective, a regulatory scheme improves welfare if sufficient rent is generated to enable a fair compensation programme. The most desirable proposal will be the one that yields the largest incomes for fishermen. Since we have little evidence on dispersion in the incomes of fishermen, we focus on changes in average fishing incomes and ignore the distribution.

Welfare Evaluation Results

When evaluating the distributional consequences of alternative fisheries regulatory proposals, it is important to take into account conditions in the labour market. If full employment prevails, loss of a job in the fishery will impose small (financial) losses on fishermen. But in a low-employment economy, alternative employment may not be available for displaced fishermen so that financial losses will be substantial. In this article, we focus on a low-employment scenario and assume

7. It is beyond the scope of this analysis to evaluate the non-monetary costs associated with the loss of a well-loved job in the fishery, although this is clearly an important issue.

that individuals losing employment in the fishery are forced to rely on social assistance benefits of $5,160 annually.[8]

Note that it is only possible to assess distributional implications if it is known how *both* the benefits and the costs of a regulatory proposal will be allocated. We believe that the assumptions made here about how the rent gains obtained through rationalization will be distributed are consistent with each of the methodologies employed. The conclusions obtained, however, are valid *only* if rents are distributed as in our simulations. We are not advocating a system of hypothetical compensation.

The two regulatory alternatives we compare to the status quo (Case I) were suggested by a review of material about the fishery (Fleet Reduction Committee 1982; Pearse 1982). In Case II, we assume the number of vessels making up each of the four types is reduced by one-third (to 3,514 vessels) and the total catch of each vessel type in 1982 was distributed equally to each remaining vessel.[9] In Case III, we assume that only the existing number of seine vessels—of which there were 539 in 1982—are permitted to share evenly in the total salmon catch of 1982. We simulate this second alternative because some observers have suggested that this vessel type is the most efficient (Pearse 1982) and capable of taking the entire catch at least cost. A comparison of rents in Cases II and III can be used to establish the efficiency costs of permitting inefficient vessels to remain in operation. Alternatively, using the methodologies described in this article, we also can examine the distributional impacts of a policy that creates a more efficient, but undoubtedly smaller, fleet that offers far fewer fishing employment opportunities (Case III) with those of a policy that lets more fishermen participate in the fishery (Case II).

We look first at the extent of rent generation from fishery rationalization (Table 5). Predicted status quo rents for the entire fishery using cost function estimates are - $26.49 million (1982 dollars). In the status quo case, only the gillnet-troll sample earns a positive rent. Rents increase to $22.13 million in going from Case I to Case II, thereby providing evidence of potential efficiency gains through adoption of a

8. Unemployment insurance benefits would be available initially for some displaced fishermen. But because such benefits would only be available for a limited period, we prefer to make the more "long-run" assumption of independence on social assistance. It should be noted that we did conduct a full set of simulations using the full-employment assumption. Not surprisingly, with minimal income losses both regulatory proposals were welfare-improving relative to the status quo.

9. Pearse (1982) suggests that the fleet could be reduced by one-half, while the Fleet Reduction Committee (1982) provides a more conservative estimate of one-third. In addition, Pearse recommends that the relative proportions of vessel types remain at their preregulatory values.

quota scheme.[10] By the same token, total employment is reduced by 2,637 (a reduction of 26 percent). In Case III, we find that each seine vessel's catch is approximately double its actual 1982 catch. Total crew size for seine vessels does not change (2,808), but this now represents entire employment in fish harvesting. Fishery rent rises to $110.03 million in 1982 dollars, a substantial increase over rents of either Cases I or II. These results suggest the possibility of potential returns to scale that are not exploited because of the presence of too many vessels on the fishing grounds. The simulations show clearly a trade-off between increased rent from and decreased employment in the fishery. Using the framework developed in the preceding section of this article, we then measured these trade-offs.

Utilitarian Results

The utilitarian results are unambiguous (Table 6). Both regulatory alternatives are preferred to the status quo, and the all-seine scheme ranks first. These results hold regardless of the level of inequality aversion adopted. From the utilitarian perspective, the serious income losses experienced by fishermen losing jobs in the fishery are not weighted as heavily as the income gains received by low-income members of the British Columbia population through the distribution of rent gains in equal shares. The quota case (Case II) generates an increase in rent of $36.67 per person in British Columbia, and the all-seine case (Case III) generates an increase of $70.85 per person. Recall that fishermen with jobs in the fishery are not members of the low-income population. While fishermen who lose their jobs in the fishery become poor as they are forced to rely on social assistance payments of $5,160 annually, they still do not rank at the very bottom of the income distribution.

Rawlsian Results

The Rawlsian results are similar to the utilitarian results (Table 6).[11] Both regulatory proposals are preferred to the status quo regardless of

10. The adoption of a quota policy would likely entail the use of equal shares (at least to begin the programme). With no restrictions on the transfer of quota, one would expect that over time vessels would have different amounts of quota. This would result in a more efficient use of resources (and thus higher rents than represented in Table 5).

11. This is not surprising since both measure well-being in terms of income and distribute rent gains in equal shares to the population of British Columbia. The essential difference between the two approaches is that the Rawlsian approach censors the income distribution at the poverty line ($5,949) to focus attention on the "worst-off" group.

TABLE 5 Number of Vessels, Employment, and Rent for Alternative Cases

	Case I	Case II	Case III
Number of Vessels			
Seine	539	378	539
Gillnet	1,331	1,120	—
Troll	1,638	1,176	—
Gillnet-troll	1,020	840	—
Total	4,528	3,514	539
Employment (skipper plus crew)			
Seine	2,808	1,944	2,808
Gillnet	1,683	1,386	—
Troll	3,960	2,772	—
Gillnet-troll	1,632	1,344	—
Total	10,083	7,446	2,808
Rent (millions of 1982 dollars)			
Seine	-4.95	+12.51	+110.03
Gillnet	-19.43	-11.03	—
Troll	-15.91	+2.03	—
Gillnet-troll	+13.80	+18.62	—
Total	-26.49	+22.13	+110.03

TABLE 6 Welfare Evaluation Results for Alternative Choices of the Inequality-Aversion Parameter, r: Utilitarian and Rawlsian Approaches (dollars)

r	Case I	Case II	Case III
Utilitarian Approach[a]			
1.0	15,139	15,151	15,164
0.5	13,056	13,071	13,089
-0.5	8,047	8,104	8,148
-1.0	5,872	5,944	6,006
-5.0	1,780	1,826	1,868
Rawlsian Approach[b]			
1.0	5,230	5,234	5,240
0.5	5,058	5,065	5,074
-0.5	4,487	4,512	4,531
-1.0	4,067	4,102	4,133
-5.0	1,779	1,825	1,867

a. Increase in per capita rent share with respect to Case I is $36.67 in Case II and $70.85 in Case III.

b. With a poverty line of $5,949, the number of poor increases from 480,250 (Case I) to 483,986 (Case II) to 487,525 (Case III).

the level of inequality aversion chosen, and the all-seine scheme is the most-preferred choice. To understand this result, it is important once again to recognize that no fishermen are initially members of the worst-off group. Furthermore, from the Rawlsian perspective income losses suffered by those above the poverty line are not regarded as socially relevant. Thus, while 3,736 fishermen become poor under the quota scheme (Case II) and 7,275 become poor under the all-seine scheme (Case III), their income losses are measured from poverty level ($5,949) rather than from actual income (with a mean of $12,079). Regardless of the fisherman's initial income, the income loss is measured as $5,949 - $5,160 = $789. Measuring losses in this way substantially reduces their apparent magnitude. Finally, since ex-fishermen receiving social assistance payments are still not among the "poorest of the poor", their losses cannot outweigh the income gains obtained by the extremely poor group as a result of the distribution of rent gains in equal shares.

Entitlement Results

Since fishermen are currently receiving positive incomes, we assume that the government or other factors bear the burden of the negative rents associated with the current limited entry programme. Rent gains achieved from regulatory change must first be used to compensate the government or other factors. Only the surplus (that is, the positive rents obtained) can be used to fund the compensation scheme, with the remainder being distributed among all fishermen. Once again, from this perspective both alternatives are preferable to the status quo, with the all-seine case (Case III) the most-preferred policy choice.

The entitlement results are presented in Table 7. The first section of the table shows average incomes of fishermen by vessel type and regulatory alternative. In the initial situation, the average fishing income is estimated to be $12,079, compared with an all-British Columbia average annual income of $15,209 and a poverty line of $5,949. For the quota case (Case II), if no compensation or rent distributions are made to fishermen, average income received by fishermen (including those who are simulated to lose their jobs and thus to rely on social assistance payments of $5,160) falls to $9,487. For the all-seine case (Case III), income losses are even more substantial as average income falls to $7,124.

The second section of Table 7 shows how the distribution of rent gains among fishermen can increase their incomes. If the surplus rent generated is used, first, to guarantee that no income losses occur by compensating for loss of fishing entitlements and, second, to increase fishing incomes through a distribution of the surplus in equal shares to

TABLE 7 Welfare Evaluation Results: Entitlement Approach

Vessel Type	Case I	Case II	Case III
Average Incomes[a]			
Seine	12,283	9,881	12,211
Gillnet	11,639	9,352	5,160
Troll	12,939	9,566	5,160
Gillnet-troll	12,520	8,755	5,160
All[b]	12,079	9,487	7,124
Average Incomes[a] *Plus Rent Share*[c] *(low-employment scenario)*			
Seine	12,283	14,071	18,240
Gillnet	11,639	13,427	17,596
Troll	11,939	13,727	17,896
Gillnet-troll	12,520	14,308	18,477
All[b]	12,079	13,867	18,036

a. Incomes are averaged over both fishermen remaining in the fishery and those excluded (who now receive social assistance payments of $5,160 annually).

b. Average per capita income in British Columbia is $15,209; the poverty line is $5,949.

c. This is an equal share of the total positive fishery rent.

all fishermen (those retaining as well as those giving up their jobs through the compensation scheme), average fishing incomes increase. For the quota case (Case II), a surplus rent of $1,788 per fishermen is left after buying out fishing entitlements. When distributed in equal shares to fishermen, this yields an average income of $13,867. For the all-seine case (Case III), a surplus of $5,957 per fishermen after compensation yields an average fishing income of $18,036. This is significantly above the provincial average.

Conclusions and Policy Implications

An empirical evaluation of two particular individual vessel quota schemes for the British Columbia salmon fishery indicates that they would be preferred on both efficiency (rent gains) and equity (income distributional effects) grounds to a status quo position of limited entry with input controls. This conclusion is robust for the three very different methods employed here—utilitarian, Rawlsian, and entitlement—to evaluate the distributional consequences of policy change. It should be noted, however, that our analysis is incomplete in several respects. First, more detailed information is needed about the incomes of fishermen, as well as about the characteristics of the households in which they live. Second, the non-monetary losses associated with loss of a job in the fishery were not dealt with. Finally, fishery regulations in a low-employment economy may mean fishermen must relocate, but we were unable to assess the associated negative consequences for the local (often isolated) communities. These are important issues, and our inability to deal with them in this research should be kept in mind when evaluating results.

This comparison of quota schemes using alternative regulatory tools revealed an interesting dichotomy. In our earlier examination of the imposition of a royalty tax in the British Columbia salmon fishery (Dupont and Phipps 1991), we found that the potential rent gains from adopting a royalty tax were smaller than the rent gains observed here for the quota schemes. We conclude that the profit-maximizing firms in the earlier study were able to continue dissipating fishery rent, thereby leading to lower rent gains from rationalization. The vessel quota scheme described in this article does not permit such behaviour because it is in each fishing firm's interest to minimize the cost of taking a given allocation. Here, larger rent gains from quotas mean larger income gains for either the entire British Columbia population or the fishing population, resulting in the quota being preferred to the status quo according to an equity, as well as an efficiency, criterion. In contrast, we found in the earlier study that the royalty tax is preferred to the status quo according to the utilitarian (but not the entitlement) perspective. This comparison suggests that the quota is preferable to a royalty tax.

Our conclusion about the dominance of the quota over a royalty tax may result from the particular choices made for implementation of each scheme, and thus, since the models of profit-maximization and cost-minimization are not strictly comparable, it cannot be generalized. Nonetheless, the rent-dissipation argument is a compelling one that favours the choice of a quota to encourage the fisherman to operate in a more socially desirable manner (Moloney and Pearse 1979).

Two further issues that touch on the practical aspects of quota administration deserve discussion. The first is a general concern with potential management problems, especially those related to monitoring and enforcement. Scott and Neher (1981) worry that quotas may be more difficult to monitor than an input control programme (such as the limited entry programme currently in place in the British Columbia salmon fishery). Copes (1986) discusses a variety of ways in which fishermen can undermine the success of a quota programme. These methods include underreporting catches, throwing overboard less desirable fish (especially in a multispecies fishery), and deliberate and continued capture of more than one's quota.[12]

12. Indeed, these problems are not unique to a quota management scheme. Royalty taxes also encourage the first two types of behaviour.

While quantification of these costs is beyond the scope of this article (and, indeed, the requisite data are not available), both theoretical (Scott 1979, 1988; Clark 1985) and empirical evidence (Clark et al. 1988; Geen and Nayar 1988) support the view that management costs for quotas may be *lower* than for other types of fisheries regulations. A system of individual vessel quotas does require high setup costs, but both monitoring and enforcement costs are expected to fall over time once fleet redundancy is reduced.[13] Over time, the remaining fishermen begin to have a personal stake in the continued well-being of the fishery and to be both self-monitoring and self-enforcing (Scott 1988). In the interim, a system of penalties can discourage the undesirable types of behaviour cited above (Clark et al. 1988).

The second issue concerns the suitability of quotas in a fishery with a stochastic fish stock, as is the case for British Columbia salmon. Under the existing regulatory scheme, employees of the Department of Fisheries and Oceans estimate each year the salmon stock for the upcoming year in order to allow fisheries managers to make a projected estimate of the total allowable catch (the difference between the total stock and the escapement—that is, the number of fish that escape capture and go on to spawn)—see McDonald (1981); ESSA (1982); MacDonald (1982). As the season progresses, on-site managers use openings and closings of specific areas to meet escapement targets. Given the stochastic nature of the fish stock, this creates uncertainty about the total allowable catch in any given year needed to meet the sustained yield target and, more important, the catch in a given area during a given time period. Any quota programme (and indeed any change in the current fishery regulations) would need to deal with this uncertainty. There are both pessimists (Copes 1986) and optimists (Pearse 1982) about the degree of success of quota programmes in light of this type of uncertainty.[14]

13. Clark et al. (1988) argue that quotas can ease entry/exit decisions by reducing the administrative obstacles to these types of behaviour. This likely results in a greater reduction in surplus vessels than would a royalty tax. Fewer vessels mean lower management costs and fewer problems for regulators. In practice, Clark et al. (1988) have found that the transition from limited entry to quotas for all significant commercial New Zealand finfish fisheries has been very smooth. Such a smooth transition could not be expected with royalty taxes because fishermen bitterly resent this type of regulation. A further consideration placing quotas ahead of royalty taxes is that the time profile of management costs associated with a system of royalty taxes shows both high start-up costs and high continuing administrative costs.

14. Pearse (1982), in his Royal Commission report on the West Coast fisheries, initially recommended that royalty taxes be used in the salmon fishery in order to reduce by half the number of participating vessels. Ultimately, however, he saw quotas as a better management tool that could both control the total catch of the fishery and generate resource rent.

Several modifications to the structure of the quotas suggested in this article would make it easier for the regulator to deal with the problems caused by uncertainty. First, since the infrastructure for on-site management is currently in place, the regulator could incorporate this expertise into organizing a system of quotas that are both area- and time-specific. Second, the regulator should define quotas as shares of the total allowable catch, not as pounds caught. This makes it easier to downsize or increase fishing activity (Clark et al. 1988). Third, the regulator should allow trades (sales) of quotas to take place after the catches have been taken in order to discourage fishermen from taking more than their allotted catches and to adjust individual harvest expectations with actual catch. Finally, the regulator could enter the quota market as a buyer or seller, as required. This would give the regulator much tighter control over the total allowable catch (thereby achieving the stock conservation objective) than does the limited entry programme currently in place.

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