RENTS AND RENTS DRAIN IN THE ICELANDIC COD FISHERY

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ABSTRACT

This paper estimates current resource rents being generated in the Icelandic cod fishery and compares them to the maximum sustainable attainable ones. For this purpose a simple aggregative model of the cod fishery is specified and empirically estimated. It is found that in spite of the cod stock being in a fairly depressed state, substantial economic rents are currently being generated in this fishery. No doubt this is primarily due to the effects of the ITQ system in this fishery. Current rents, however, are only about a third of the rents that would pertain in a profit maximizing sustainable position of this fishery. Thus, compared to the maximum, the Icelandic cod fishery appears to be subject to significant rents loss. Most of the rents gain from the current position of the fishery to the profit maximizing sustainable position is due to an increased cod stock. A much smaller part is due to reduced fishing effort.

Keywords: Fisheries rents, fisheries rents drain, Icelandic cod fishery

INTRODUCTION

This report presents estimation of rents generation and rents loss in the Icelandic cod fishery. Rents are calculated on the theoretical basis set out in [1]. Current rents are calculated with reference to a base year (2005). Rents loss is measured as the difference between current rents and the maximum sustainable rents. The fishery is modeled in a simple, aggregate way. This approach is primarily to limit the amount of research work necessary. The construction of a reasonably complete, disaggregated (with respect to sub-stocks, cohorts, vessel classes and fishing gear) model of the Icelandic cod fishery is a major undertaking. Previous research employing both approaches [2,3] indicates that the errors of adopting a simple, aggregative simple model for the Icelandic cod fishery instead of a more complete, disaggregated model are not substantial.

THE ICLANDIC COD FISHERY: BACKGROUND

The Icelandic cod fishery is a sizable part of the global ocean fishery. Annual catches have traditionally been in excess of 300.000 metric tonnes (mt) annually. The unit value of landings is high (prices in 2007 were around 3 US$ per kg.). Thus, the landed value of the fishery is potentially about 1 billion US$. This may be compared to the estimated value of global marine capture fisheries landings of some 80 billion US$[4]. In the past, however, this fishery has been greatly overexploited. As a result, current stocks are quite depressed: estimates suggest that the fishable stock in 2007 was only about 30% of the virgin stock [5]. Attempting to rebuild the cod stock have led the fisheries authorities to constrain total allowable catches (TACs) to around 200.000 mt. or about 60% of the MSY for several years. This has halted the stock decline but not produced much in terms of stock recovery. The path of stocks and catches is illustrated in Figure 1.
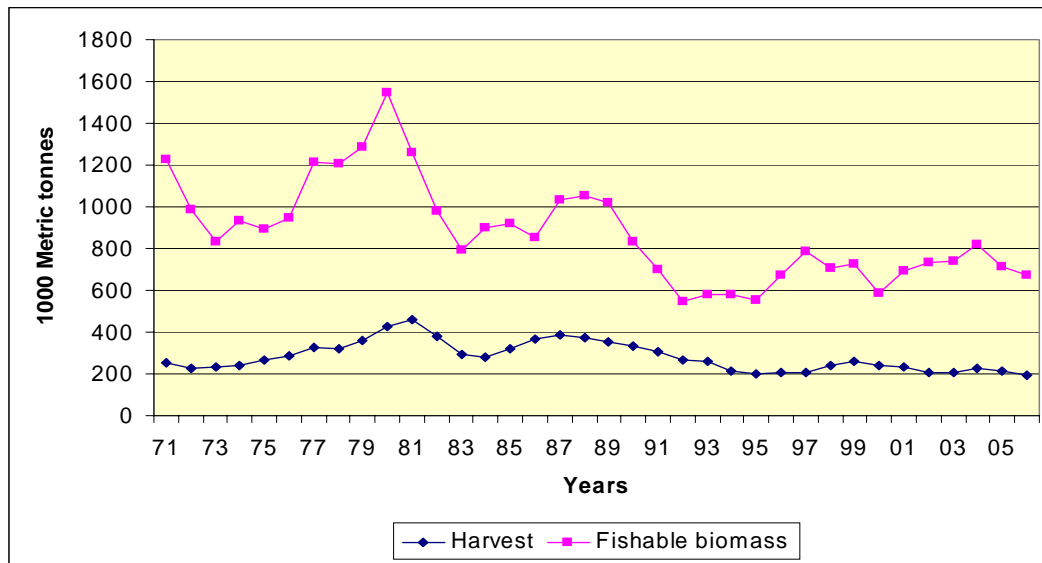
Fig. 1 The cod fishery: Fishable biomass and landings (1000 mt)

The cod fishery is pursued throughout the year, which a peak during the spawning season when large fish become highly catchable. It is conducted both in inshore and off-shore waters by several vessel types ranging in size from about 5 to 3000 GRT (gross registered tons) and employing different types of fishing gear. In terms of landed quantity, however, the most important part of the fleet are deep-sea, bottom trawlers ― typically 500-1500 GRT ― many of which are freezer/factory trawlers.

The cod fishery is by far the most valuable component of the Icelandic demersal fisheries. These fisheries involve some 20 species of significance with cod haddock, saithe, redfish and Greenland halibut (turbot) being the most important. In any given fishing trip, one of these species tends to be targeted. However, it is not common to haul in a clean, one species harvest. In some fishing trips, especially the longer ones, a mix of two or more species is targeted.

Most vessels pursuing cod and other demersal fisheries were subjected to a form of ITQs (individual transferable quotas) in 1984. The ITQ system was substantially strengthened and expanded in 1991 although the small vessels (under 6 GRT) were still largely exempted from the ITQ restrictions. These small vessels were brought into the ITQ system in 2004.

Under the ITQ system, especially from 1991 onwards, various steps have been taken to restore the cod stock. Most important of these measures have been severe cut-backs in total allowable catches (TACs). Others important measures have been extensive time and area closures. As can be gauged from Figure 1, these measures have halted the decline in the stock, but have not managed to significantly increase it. Interestingly, similar measures for other demersal stocks, most notably the haddock stock, have produced much better results (Figure 2).
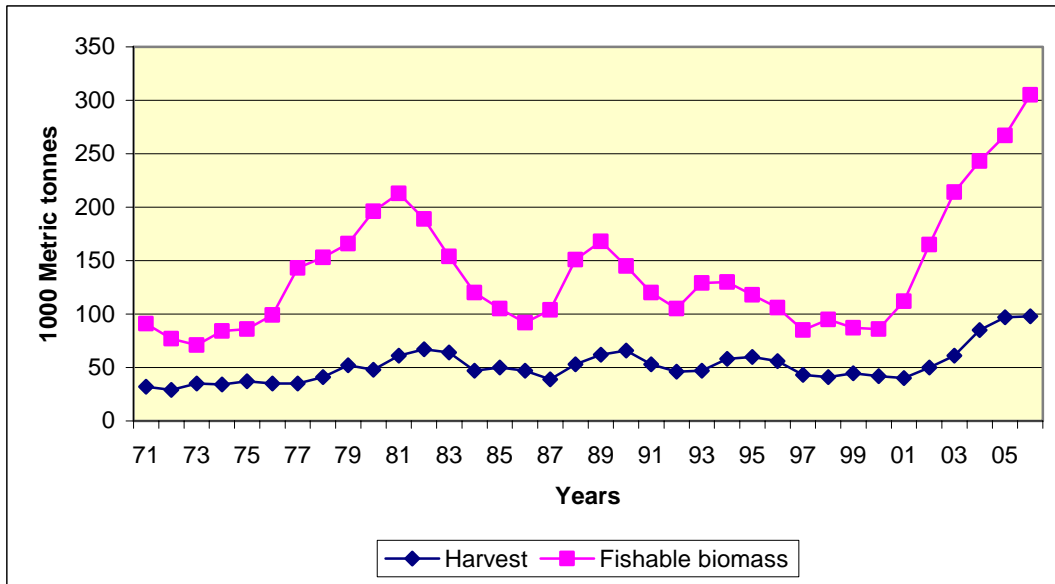
Fig. 2 The haddock fishery: Fishable biomass and landings (1000 mt)

Under the ITQ system the size of the demersal fishing fleet as well as the demersal fishing effort (including that on cod) has substantially contracted [4]. This as well as several other measures undertaken by the fishing firms, has greatly increased the economic performance of the fishery. Thus, productivity in the fishing industry has increased at a rapid rate. Similarly, the profitability of the fishing firms has greatly improved. These developments have been reflected in a huge increase in the market value of the ITQs. These and further data regarding the economic and biological impact of the ITQs are recounted in [4,5]

THE COD FISHERIES MODEL

To describe the cod fishery, the following basic fisheries model is adopted:

$$\dot{x} = G(x) - y \qquad \text{(Biomass growth function).} \qquad (1)$$

$$y = Y(e, x) \qquad \text{(Harvesting function).} \qquad (2)$$

$$\pi = p \cdot Y(e, x) - C(e) \qquad \text{(Profit function).} \qquad (3)$$

$$p = P(y) \qquad \text{(Landings demand function)} \qquad (4)$$

The five variables of this model, i.e. x, y, π, p and e represent biomass, harvest, profits, landings price and fishing effort, respectively. The first four are endogenous — determined within the model. The fifth, fishing effort, is exogenous; it is a control variable for the fisheries operators. All variables depend on time, i.e., they can change over time. The derivative, $\dot{x} \equiv \partial x / \partial t$ measures the change in biomass at a point of time. Note that parameters taken to be constants such as various prices and technological coefficients are not explicitly mentioned in the above presentation of the model.

In implementing the model, the following functional specifications, suggested by econometric investigations of the data [3,6].

$$x_{t+1} - x_t = G(x_t) = \alpha \cdot x_t - \beta \cdot x_t^2,$$

$$Y(e_t, x_t) = q \cdot e_t^a \cdot x_t^b,$$

$$C(e_t) = c \cdot e_t + fk,$$

$$P(y_t) = d \cdot y_t^f,$$

where α, β, q, a, b, c, fk, d, and f are constants and t refers to time. Note that time is now in discrete units of years in accordance with the available data. The constant α is the intrinsic growth rate of the biomass, the ratio α/β, is the carrying capacity of the biomass, fk represents fixed costs, q catchability, f is the elasticity of landings price with respect to the volume of landings.

Given these functional specifications the complete model can be written in a simpler form as:

(5) $\qquad x_{t+1} - x_t = \alpha \cdot x_t - \beta \cdot x_t^2 - y_t$ $\qquad$ (Biomass growth function). $\qquad$ (5)

(6) $\qquad \pi_t = p_t \cdot y_t - k \cdot \dfrac{y_t^\delta}{x_t^\varepsilon} - fk$ $\qquad$ (Profit function). $\qquad$ (6)

(7) $\qquad p_t = d \cdot y_t^f$ $\qquad$ (Price function). $\qquad$ (7)

In this formulation of the model the fishing effort variable has been substituted out. The endogenous variables are now x, π and p. The exogenous (or control) variable is y. It is easy to check that the new constants k, δ and ε are the following transformation of the original constants: $k = \dfrac{c}{q^{1/a}}$, $\delta = 1/a$ and $\varepsilon = b/a$.

Econometric and other estimation of the constants in the cod model defined by (5), (6) and (7) led to the following results [3, 7].

| Table 1 **Estimated coefficients** (All values are in ISK. Exchange rate: 61 ISK per US$)		
Coefficients	Estimates	t-statistics
α	0.669853	8.6
β	3.353·10^{-4}	-2.9
k	57604.95	6.5
δ	1.1	NA (nonl. estim.)
ε	1.0	NA (restricted)
fk	10 b.	NA (from cost accounts)
d	220.0	14.8
f	0	NA (restricted)

For the logistic function it is easy to verify that the maximum sustainable yield, MSY, and the stock carrying capacity, XMAX, say, are given by the expressions:

$$MSY = \frac{\alpha^2}{4 \cdot \beta},$$

$$XMAX = \frac{\alpha}{\beta}.$$

It then follows from the estimates in Table 1 that the estimated MSY=335 and the estimated XMAX=1998 thousand mt (metric tonnes).

Figure 3 provides a summary description of this fishery. The figure is drawn in the space of (fishable) biomass and landings (harvest) and applies at each point of time and, therefore, also in equilibrium. The parabolic graph represents the biomass growth function. As can be seen, it covers

Figure 3 The estimated fisheries model (Biomass growth and iso-profits in biomass-harvest) -space)
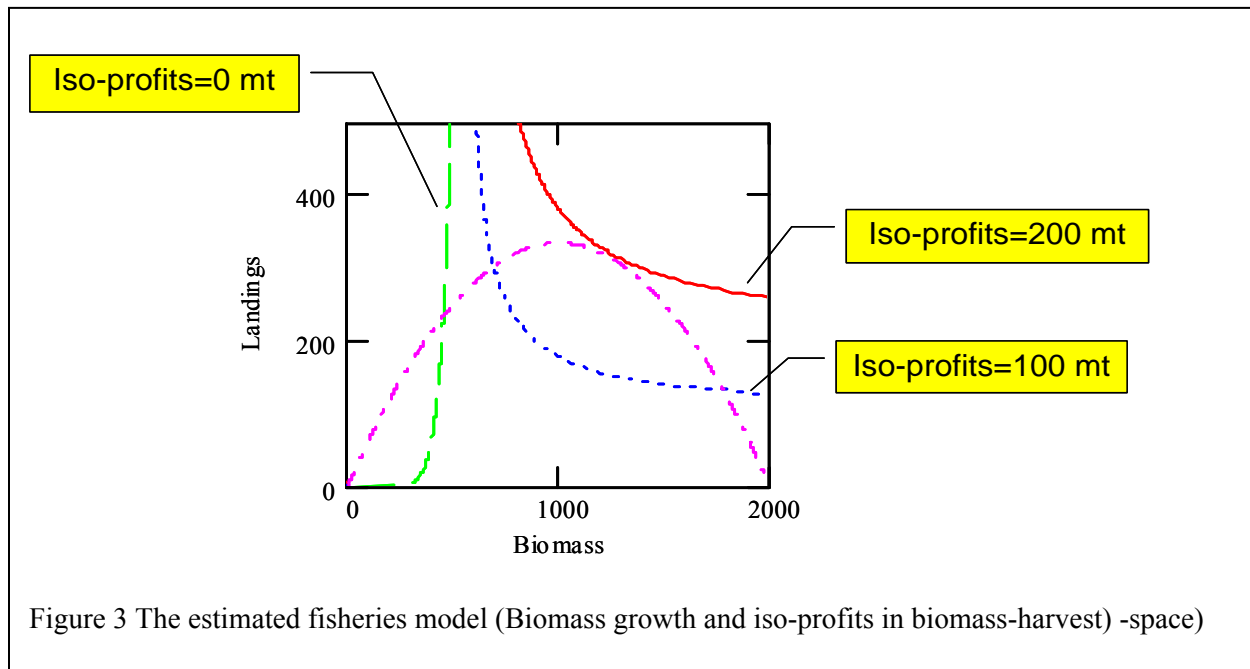
biomass from zero to the carrying capacity of almost 2 million mt. and has a maximum sustainable yield of about 335 thousand mt. If, for any biomass level, landings lie on this curve, a biological equilibrium prevails. The other curves in this diagram are variable iso-profit curves, i.e. loci of biomass and harvests which represent constant variable profits (measured in cod volume units). Any point where these curves intersect the biomass growth curve represents a sustainable fishery with the corresponding variable profits. Thus, the traditional, zero-profit bioeconomic equilibrium is found where the zero-iso-profit curve intersects the biomass equilibrium curve. This happens, as indicated in the diagram, roughly where biomass is less than a quarter of the virgin stock equilibrium. The highest sustainable profits are obtained where an iso-profit curve is a tangent to the biomass growth function. As the diagram suggests, this occurs at biomass of some 1300 thousand mt. and harvest of over 300 thousand mt. At this point, annual variable profits from the fishery (approximately rents) amount to approximately 200 thousand mt. of cod.

ESTIMATE OF RENTS AND RENTS LOSS

According to [1] rents at any time, *t*, harvest and biomass level are defined as:

$$Rents_t = \left(\frac{d\pi_t}{dy_t}\right) \cdot y_t,$$

where π_t represents profits and y_t harvest. For the profit function specified in section 2, this equation is:

$$Rents_t = p_t \cdot y_t - k \cdot \delta \cdot \frac{y_t^{\delta}}{x_t^{\varepsilon}}. \qquad (8)$$

Comparison with the profit function (6), shows that in this case rents are unambiguously less than variable profits. This is because the profit function is strictly concave in harvest ($\delta > 1$). Note that rents may be greater or less than total profits depending on the level of harvest and biomass.

Given (8) and the fisheries model specified above, it is now an easy matter to estimate current rents and rents loss. The latter, as explained in the introduction, is merely the difference between rents at the point of maximum sustainable profits and current rents. The results are given in Table 2 below:

Table 2 **Rents and rents drain: Main results** (Amounts in m. US$)			
	Current (2005)	Optimal	Difference
Biomass (1000 mt)	715	1241	+526
Harvest (1000 mt)	215	315	+100
Effort (index)	1.0	0.86	-0.14
Total profits (m. US$)	126	546	+420
Variable profits (m. US$)	290	710	+420
Rents (m. US$)	241	667	**+426**

So, it appears that in spite of its biologically depressed state, the Icelandic cod fishery is currently generating substantial economic rents as well as profits. However, compared to maximum attainable profits, the fishery suffers from rents loss of some 426 m. US$ per year. In terms of current rents and the size of the fishery this rents loss is very substantial. It should be noted, however, that to realize these potential rents, requires intensive rebuilding of the cod stock and to a lesser extent reduction in long term fishing effort. The former leads to substantial increase in sustainable catches which are responsible for most of the economic gain.

4. Sensitivity and confidence intervals

The above estimates are subject to uncertainty. This uncertainty has many sources. There is uncertainty about the current state of the fishery, which is needed to estimate current rents. Similarly, there is uncertainty about both the values of the parameters of the model used to calculate maximum future rents. Finally, there is uncertainty about the model itself. The first three types of uncertainty may be expressed as uncertainty about the numerical specifications of the current fishery and model parameters and the current state of the fishery. The importance and extent this uncertainty may be assessed by (i) sensitivity analysis and (ii) stochastic simulations.

In sensitivity analysis some of the more crucially numerical assumptions of the model are varied over some reasonable interval and the outcome of the model recalculated for these modified assumptions. These kinds of calculations provide an idea of how sensitive the outcomes are to the assumptions.

In stochastic simulations, which are often referred to as Monte Carlo methods, stochastic distributions for the numerical assumptions are specified. By repeatedly drawing random values from these distributions and calculating the resulting model outcomes one may obtain an estimate of the probability distribution of the outcomes. Subsequently, on that basis, confidence intervals for the outcomes may be calculated.

Sensitivity analysis and stochastic simulations along the above lines are not well suited to assess the fourth type of uncertainty, i.e. uncertainty about the appropriateness of the model itself. To assess that, probability distributions over a set of models has to be specified and rents calculated for each one of them. This is a major task which is well beyond the scope of the this study.

Sensitivity analysis

Sensitivity analysis was conducted on the following model specifications: (i) landings price, (ii) initial biomass, (iii) the cost coefficient, k, (iv) the estimated MSY and (v) the estimated carrying capacity or virgin stock. As explained above, the last two are closely linked to the estimates of the coefficients α and β of logistic biomass growth function. The sensitivity of the estimated rents loss to these specifications is illustrated in Figure 4.

Fig. 4 Sensitivity of rents loss to basic assumptions
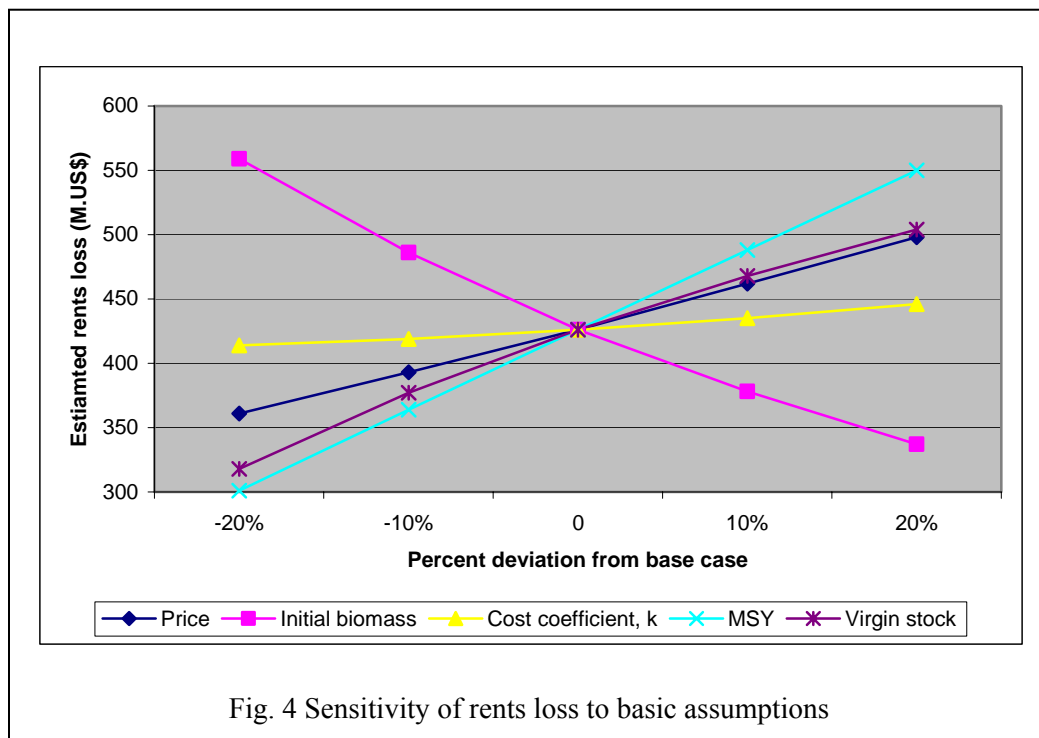
As illustrated in Figure 4, the greatest sensitivity of estimated rents loss is to the estimated initial biomass and the biological assumptions on MSY and the stock carrying capacity or virgin stock biomass. The impacts of price and the cost parameter on the estimated rents loss is less.

Confidence intervals

Confidence intervals for the rents loss are derived with the help of stochastic simulations. The stochastic simulations are quite simplistic. Stochastic distributions for the five model specifications subject to sensitivity analysis above, namely (i) landings price, (ii) initial biomass, (iii) the cost coefficient, k, (iv)

the estimated MSY and (v) the estimated carrying capacity of the stock were specified. In all cases the stochastic specifications took the form:

$$z_i = \overline{z}_i \cdot (1 + u_i),$$

where z_i denotes stochastic value, $\overline{z}_i$ the value specified in section 2 above (especially table 1 and below) and u_i is a normally distributed random variable with zero mean and some variance to be specified. It follows that each stochastic quantity z_i is normally distributed with expected value $\overline{z}_i$ and standard deviation $\overline{z}_i \cdot \sigma_{u_i}$ where σ_{u_i} is the standard deviation of the random variable u_i. In other words, the standard deviation of is a certain percentage of the expected value.

The stochastic specifications employed in the simulations are summarized in Table 3.

Table 3
Stochastic specifications

Variable	Stochastic version	Distribution of the random term	Expected value	Standard deviation
Landings price, p	$\overline{p} \cdot (1+u_p)$	$u_p \sim N(0, 0.03)$	220	11
Initial biomass	$\overline{x} \cdot (1+u_x)$	$u_x \sim N(0, 0.05)$	715	100
Cost parameter	$\overline{k} \cdot (1+u_k)$	$u_k \sim N(0, 0.1)$	57605	5761
MSY	$\overline{MSY} \cdot (1+u_{MSY})$	$u_{MSY} \sim N(0, 0.05)$	335	17
XMAX	$\overline{XMAX} \cdot (1+u_{XMAX})$	$u_{XMAX} \sim N(0, 0.07)$	1998	140

Two thousand random draws were drawn from the distributions specified in Table 3. For each set of draws rents in the base year and maximum rents and the difference between the two were calculated. Each difference represents one possible rents loss. The distribution of all these two thousand outcomes represents an estimate of the probability distribution of the rents loss. The corresponding histogram of rents loss is illustrated in Figure 5.

As may be inferred from Figure 5, the distribution of rents loss is skewed slightly to the right (a longer tail to the right). The coefficient of skewness was 0.314 (compared to zero for a normal distribution). Thus, the distribution is not quite normal. In accordance with this, the estimated mean rents loss was 428 m. US$ and the estimated median loss was 422 m. US$. Compare this to the non-stochastic estimate of random loss derived in section 3 (esp. Table 2) of 426 m. US$.

Fig. 5 Stochastically simulated rents loss: A histogram
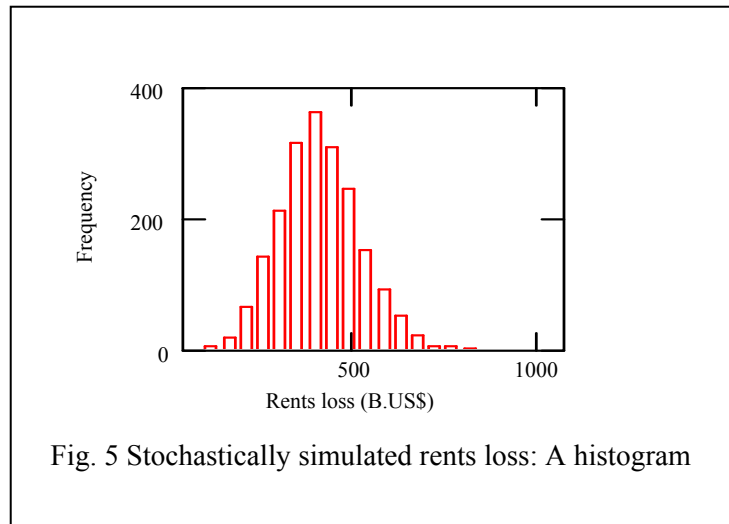
An estimated distribution function for the outcomes is drawn in Figure 6. On the basis of this distribution function, confidence intervals for the rents loss are easy to calculate. A 95% confidence interval for the rents loss is 233 to 655 m. US$. A 90% confidence interval for the rents loss is 257 to 610 m. US$.

Fig. 6 Rents loss: An estimated distribution function
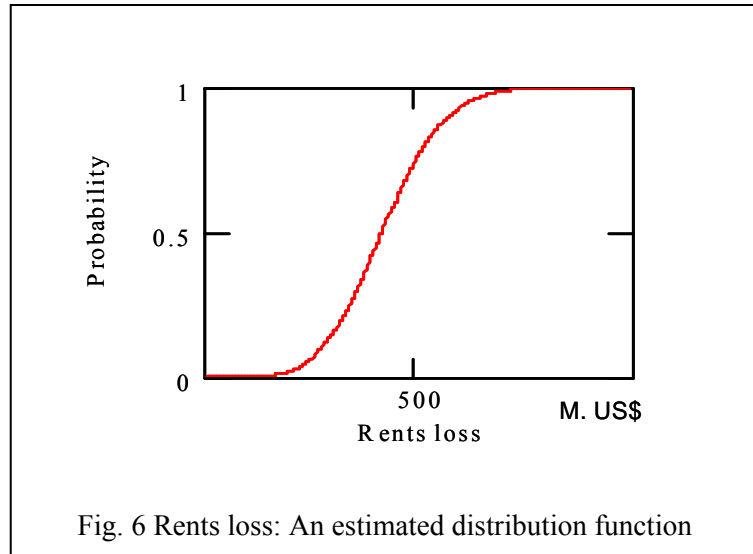
SUMMARY AND CONCLUSIONS

According to the above, the Icelandic cod fishery, in spite of being biologically quite depressed, is currently generating substantial economic rents. These rents, however, are only just over 1/3 of those attainable at the economically optimal sustainable point of the fishery. To reach that point, the cod biomass must be increased greatly (almost by 3/4) and fishing effort reduced by about 14%. Needless to say, this kind of change cannot be effected quickly ― most likely it will take several years even if all fishing for cod was immediately halted. It follows that in terms of present value, the potential rents gain is substantially less than that mentioned above.

The difference between current rents and those corresponding to the optimal point of the fishery is approximately 426 m. US$. The Icelandic cod fishery is currently generating about 1% of the revenues of the global fishery. Thus, if the rents loss in this fishery is representative of the global rents loss, the latter would be about 43 b. US$ per year. This figure is in the lower to mid range of the interval suggested in an aggregative global study of the fisheries rents loss [8].

These results are only estimates based on a fairly simplistic representation of the fishery and numerical assumptions. Sensitivity analysis suggests that the calculated rents losses are most sensitive to the empirical assumptions about the initial stock size, the MSY and carrying capacity of the biomass growth function and the price of landed catch. Stochastic simulations over these and other empirical specifications suggest that a 95% confidence interval for the rents loss is between 233 and 655 m. US$. Expanding this to the global fishery as above suggests that a similar confidence interval for the global fisheries rents loss would be 23 to 66 b. US$ per year.

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