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Minimum information management systems and ITQ fisheries management

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Abstract

In 1986 New Zealand reformed its fisheries management regime with the introduction of a rights-based system of management. At the beginning of each fishing season a government agency sets an allowable commercial catch. Individual firms hold an entitlement to harvest a share of the allowable commercial catch. To date, the government agency has relied almost exclusively on the results of stock assessment research when setting the allowable harvest. Excessive reliance on biological data in fisheries management has attracted criticism. An alternative, a minimum information management system, uses information contained in quota prices as a guide to set limits on commercial harvest. This paper examines price formation in one quota market. We find evidence in the data that supports the use of quota prices to guide the setting of limits to commercial harvest. Furthermore, time-series analysis provides a basis for studying the temporal response of changes in asset prices to perturbations in the allowable harvest. The results illustrate how information summarized in quota prices can complement the findings of stock assessment research in fisheries management.

Keywords: Econometric analysis of ITQ prices; Application to fisheries management

1. Introduction

Regulated access and transferable rights are two alternative institutional arrangements for managing fisheries. Anderson and Lee [1] describe optimality in the context of regulatory

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instruments. Clark [8] and Arnason [3] have shown that transferable harvesting rights are efficient provided the market is competitive and the allowable harvest is optimal. In theory, both approaches seek to produce an outcome that makes coincident the shadow value of an additional unit of the biomass and the individual firm's valuation of an additional unit of harvest. In operation, both approaches require information—biological and economic—for deriving the parameters necessary for implementing policy.

The failure of management regimes to arrest population declines in many fisheries has been linked inter alia to the inability of fisheries science to provide adequate information upon which to base stock management [19,23]. There is growing skepticism that marine systems can somehow be managed through use of quantitative biological models. Science and technology, no matter how lavishly funded may be unable to provide timely solutions to resource or conservation problems [16]. In the case of output-controlled fisheries, knowledge of fisheries biology may not be sufficiently well developed to provide the sole basis for setting catch quotas [17].

The information problem becomes relatively more acute in input-controlled fisheries where management is directed towards bioeconomic optimality. Homans and Wilen [14] show how data on fishing capacity, harvest and profitability are integrated with biological data to estimate equilibrium values for capacity, season length and biomass. This non-trivial exercise would have to be applied by managers in numerous fisheries within an exclusive economic zone and repeated at regular intervals in order to generate information that kept abreast of changes in technology, market conditions, and the biomass. In contrast, rights-based management systems provide a basis for an information generating mechanism that could prove useful in fisheries management. Building on the classic work of Smith [20], Hayek [11] asserted that a notable fact about the price system is the economy of knowledge with which it operates. A significant line of research has explored the relationship between the knowledge of individuals and how market outcomes are affected by the rules of the market [21]. In the case of fisheries management, Arnason [3] argues that the information necessary to optimally adjust regulated limits to annual harvest is contained in quota prices. In this paper we examine the information content of quota prices.

In 1986 New Zealand introduced a quota management system (QMS) based on individual transferable quota (ITQ) rights operating within an administered total allowable catch (TAC). The TAC covers all mortality to a fish stock caused by human activity. When setting the annual total allowable commercial catch (TACC) the Minister of Fisheries is required to have regard to the TAC and allow for non-commercial fishing interests (TNCC). Thus the TAC = TACC + TNCC. Individual firms hold an entitlement to harvest a share of the annual TACC. Estimates of recreational catch are derived from surveys.

The QMS relies on biological models to provide estimates of maximum sustainable yield (MSY), and current and projected stock biomass (B) levels. Records of annual landings, estimates of catch per unit effort (for some fisheries) and, in sports fisheries, estimates of recreational harvest, are made available to the stock assessment consultative process. Prior to the beginning of each fishing season the consultative process, involving biologists, fisheries managers and other stakeholders, considers the available information and makes recommendations to the Minister of Fisheries as to the most appropriate level for the TAC. Legislation requires administrators to manage stock levels toward B_{MSY} adjusted by social and economic considerations. To date, the TAC-setting process has relied exclusively on information from biological models and harvest records.

The QMS involves a market-based mechanism and it seems reasonable to assume that ITQ prices convey information on market expectations over a range of variables that co-determine profitability. Although these data are readily available they have yet to be used in the TAC decision-making process. What is the prospect of increasing the role of information contained in quota prices in the management process, possibly as a partial substitute for information generated by stock assessment research? In other words, is it possible to use information summarized in quota prices as an indicator of the bioeconomic state of the fishery? Two benefits could flow from greater reliance on quota prices. First, a net cost saving would follow to the extent that research into quota price information is substituted for stock assessment research. Second, and possibly of greater economic significance, there could be potential benefits from incorporating contemporary market expectations when setting the annual TAC.

Consider, for example, data from one of New Zealand's snapper (*Chrysophrys auratus*) fisheries. Table 1 shows the TACC, landings, average asset price and average lease price for the snapper one quota management area (SNA 1) for the years 1989–98. What information do the quota prices convey? In general, we would expect current lease prices to provide an indication of current profitability in the fishery. Asset quota prices should reflect expectations about discounted future profitability in the SNA 1 fishery. These expectations will include all possible impacts on profitability, including biomass dynamics, institutional change, market conditions, and so on. Can fisheries managers use market data to guide the TACC adjustment process? We seek to answer this question using 9 years' of data collected from the record of ownership and lease transactions within the SNA 1 management area. The paper is organized as follows. In Section 2 we use the model developed by Arnason [3] to derive the hypothesis for empirical analysis. In Section 3 we describe the snapper fishery and the data. Section 4 specifies the econometric models used to analyze the time series. In Section 5 we present the results of time-series analyses of quota prices and illustrate how the results can be applied to commercial fisheries management. Concluding remarks are made in Section 6.

Table 1
Snapper ownership and lease prices

Year	TACC (T)	Annual harvest (T)	Number of months with observations	Average asset price ($/T)	Average lease price ($/T)
1989–90	5981	5826	12	19,367	2208
1990–91	6002	5315	12	22,381	2585
1991–92	6010	6191	11	32,551	3196
1992–93	4904	5423	12	47,723	3965
1993–94	4928	4846	12	63,732	4896
1994–95	4938	4831	10	61,477	4657
1995–96	4938	4941	8	38,861	4028
1996–97	4938	5049	7	34,367	3526
1997–98	4500	4519	10	27,814	3011

Note: Fishing year begins in October each year. Data expressed in NZ$1998.
Source: New Zealand Ministry of Fisheries.

2. Model

In this section we analyze the broad structure of the QMS using a model developed by Arnason [3]. There are two parts to the overall model. First, we must determine the total quota Q, and allocate rights to Q across n firms, so as to maximize net present value. Rather than outlining Arnason's model in detail, we have chosen to only present the current-value Hamiltonian.

$$H = \sum_{i}^{n} [pq(i) - C(E(q(i), X)] + \mu[G(X) - Q], \tag{1}$$

where p is the catch price, $q(i)$ the firm i's harvest ($=\alpha(i)Q$), $\alpha(i)$ the firm i's share of quota, $C(.)$ the harvesting costs, E the fishing effort, X the fish biomass, $G(X)$ the natural growth function, μ the shadow price of the resource, and r the discount rate.

The solution to (1) must satisfy

$$p - C_E E_{q(i)} = \mu, \quad \text{for active firms} \tag{2}$$

and

$$p - C_E E_{q(i)}(0, x) < \mu \Rightarrow \alpha(i) = q(i) = 0 \quad \text{for inactive firms,}$$

$$\mu' = \sum_i C_E E_x + \mu(r - G_x). \tag{3}$$

Eq. (2) tells us that firm i should receive additional quota as long as the marginal profit created exceeds the shadow price of the resource. From Eq. (3) the instantaneous change in the stock's shadow price must equal the marginal impact of the stock on cost less the net value of the marginal product of the stock in situ. In order to demonstrate efficiency Arnason assumed that firms operate at the bottom of their average cost curves and that all firms are equally efficient. However if fishers are heterogeneous then the possibility of a different rent maximizing TAC exists [12].

Firm i's dynamic demand function for quota rights is derived as follows. The current value Hamiltonian for the profit maximizing firm is

$$H = pq - C(E(q), X) - sz + \sigma z,$$

where s is the instantaneous quota price, σ is the value of additional quota to firm i, z the purchases of share quota, and q is the αQ.

Variables Q,X,s,p and r are exogenous to the firm. The necessary conditions for profit maximization include

$$s = \sigma \quad \text{for active firm,}$$
$$s \geqslant \sigma, \quad \text{for inactive firms,} \tag{4}$$

and

$$\sigma' - r\sigma = -(p - C_E E_q)Q. \tag{5}$$

Thus active firms buy (sell) quota as long as the shadow price of additional rights is greater than (less than) market price. The shadow price of rights follows Eq. (5), which combined with (4), yields the following time path of quota prices:

$$s = \frac{\dot{s}}{r} + \frac{(p - C_E E_q)Q}{r}. \tag{6}$$

Eq. (6) shows current price to equal the discounted value of the change in asset price plus the present value of profit that attaches to quota. Two results follow. First, the total quota Q set by the management agency should impact quota price. In particular, ceteris paribus we expect the instantaneous price to fall as total quota increases. Second, the market value of quota provides information about current and future conditions in the fishery. Provided the quota market operates reasonably smoothly, profitable firms will harvest Q and, if Q is constraining, there will be positive rents in the fishery. If Q is sufficiently excessive, then $\sum_i^n q(i) < Q$, the instantaneous quota price will be zero and the fishery will be the usual open access fishery.

The broad parameters of New Zealand's QMS can be assessed in terms of the above model. First, it is clear that the optimal quota Q^* should be determined allowing market forces to bring out the optimal allocation of rights across fishers α^*_i. In the QMS market forces operate to allocate rights to the relatively more profitable fishers. However, the TACC is set according to a non-market process, therefore efficiency—even if we accept the assumptions in Arnason's model—hinges on whether TACC = Q^*. Under the current mechanism this is most unlikely. Second, the QMS does not provide a mechanism for allocating rights across all fishers. Each year provision is made, by way of an allowance, for the recreational harvest. In theory, if commercial (c) and recreational (r) fishers are competing for the optimal harvestable surplus then $G(X^*)$ should be divided at a rate Q_c^* and Q_r^*, respectively [7,22]. The process by which the QMS partitions the TAC into an allowance for non-commercial harvest (TANC) and commercial harvest (TACC) does not account for the relative net benefits across competing sectors [6].

We now turn our attention to the information used to set the annual TAC. The annual TAC setting process relies on historical yields; and, estimates of the virgin biomass, MSY, current surplus production, current annual yield and the ratio of the current biomass to each of these parameters, derived from biological models. To date, fisheries managers have not used quota prices in the TAC setting process. However, if the ITQ markets are functioning efficiently, then the model suggests that quota prices will convey information on the current and expected state of the fishery. We now examine the data for evidence that quota prices may provide summary information on the bioeconomic state of the fishery and whether there is potential to estimate a TACC that maximizes rent in the fishery as proposed by Arnason [4].

3. Snapper fishery

Snapper are a demersal fish occupying a wide range of habitats; they are perhaps the most well researched marine species in New Zealand waters. They are a long-lived, slow growing species, which have similar species in a number of locations worldwide. Recruitment and growth in the fishery are variable and the stock biomass at any time is characterized by year-classes of varying numbers.

There are six snapper management areas. Our data were obtained from trades of rights to harvest in the SNA1 quota management area. Since introduction of the QMS, the biomass has been estimated at 20% of estimated virgin biomass [2]. This stock produces an annual surplus that is allocated TAC = TACC + TANC. The non-commercial harvest is limited by daily bag limits and the commercial harvest is allocated according to the share each right holder has to the TACC. This share is defined as a unit of ITQ; it has legal standing as a title in perpetuity and is divisible, transferable, leasable, and bankable. Commercial landings must be matched in direct one to one proportion with a holding of quota. Two quota markets operate; ownership (perpetuity) and lease (annual) title.

There are two distinct markets for production from the fishery; a high value East Asian export market, and a domestic market [5]. A large portion of export production is auctioned in the Tsujiki Fish markets in Japan, with a minor proportion destined for emerging markets in Taiwan and South Korea. The basis of demand for snapper embodies a number of non-functional aspects along with its use as a premium species in sushimi where it is de rigueur along with species such as tuna. Harvesting is by longline, trawl, Danish seine, and set net. The commercial sector is characterized by a core of export oriented processors and a periphery of small-scale harvesters who supply the domestic market and export processors.

3.1. Data

Our data set contains 94 monthly observations of means between October 1988 and September 1998. Twelve observations are omitted due to lack of trades in the asset market. Prices have been indexed as 1998 NZ$ using the NZ CPI index. Table 1 summarizes the TACC, annual harvest, the number of observations, average asset price, and average lease price for each year. In most years the TACC sufficiently constrains annual harvest and we conjecture that rents in the fishery will be positive. Summary statistics for each variable are presented in Table 2. The concept of cointegration provides a formal framework for testing and estimating long-run equilibrium relationships among economic variables. A variable is said to be integrated $I(d)$ of order d if it must be differenced d times in order to be made stationary. If the stochastic process is stationary then we can model the process using an equation with fixed coefficients that can be estimated from past data. If a set of $I(1)$ variables are cointegrated then regressing one on the others should produce residuals that are $I(0)$. Entering these variables into the estimation equation will not produce spurious results. The formal test for non-stationarity are tests for a unit root. Unit root

Table 2
Variable summary statistics

Variable	n	Mean	SD	Minimum	Maximum	$I(d)$
A_t	94	38733.05	16776.87	17389.92	74424.80	$I(1)$
L_t	94	3538.74	1065.29	1194.13	6245.21	$I(1)$
Q_t	94	5305.23	452.11	4831.00	6191.00	$I(1)$
F_t	94	10.55	1.67	7.56	13.67	$I(1)$
R_t	94	6.28	1.36	3.34	9.68	$I(1)$

A_t is the monthly average asset price, Ministry of Fisheries, L_t the monthly average lease price, Ministry of Fisheries, Q_t the annual harvest, Ministry of Fisheries, R_t the NZ monthly average 90 day bill rate, Statistics New Zealand, F_t the monthly average FOB output price, New Zealand Fishing Industry Board.

Table 3
Tests for cointegrating relationships

Regression	R-square	DW	Test[a]	Model[b]	Test statistic
$A=f(L)$	0.7634	1.416	DF	1	−2.9940
	0.8929	0.875	DF	2	−1.9971
	0.7634	1.416	PP	1	−6.8614*
	0.8929	0.875	PP	2	−4.7320*
$L=f(A)$	0.7634	1.694	DF	1	−4.3377*
	0.7689	1.638	DF	2	−4.2469*
	0.7634	1.694	PP	1	−7.6862*
	0.7689	1.638	PP	2	−7.525

*Reject the null hypothesis that there is no cointegrating relationship at the 10% level of significance.
[a] DF: Dickey–Fuller; PP: Phillips–Perron.
[b] Model 1: Constant, no trend; Model 2 : Constant, trend.

testing suggests that the variables in our analysis may be non-stationary [10]. Table 2 describes and identifies the order of integration of each system variable as $I(1)$.

Table 3 shows both Dickey–Fuller and Phillips–Perron tests providing evidence of a cointegrating relationship between lease price and asset price. Therefore, it is plausible that the functioning of the SNA1 asset market meets Arnason's [3] requirements relating to the "smooth functioning" of quota markets.

Results of Johansen–Juselius trace tests amongst the variables finds at most one cointegrating vector [15]. The test statistic is 72.634 and the 90% critical value is 71.472. Thus, we can point to one cointegrating vector amongst the variables and reject the null hypothesis of no cointegrating relationships between the variables. The trace test statistics on the remainder do not exceed the 90% critical value.

4. Modeling ITQ prices

The equilibrium given by Eq. (6) provides a basis for examining the behavior of quota prices over time. In particular, Eq. (6) suggests that asset price should be a function of changes in asset price, profit, the opportunity cost of capital and the allowable harvest. This, of course, is similar to rational expectations models that represent current asset price as a present value function of expected future returns. Arnason [4] uses a concave function to illustrate the relationship between total quota and resource rents in the fishery. Thus, the sign that attaches to marginal rent will depend on the magnitude of total quota relative to the rent maximizing level of quota.

4.1. Model specification

The information set generated by the QMS is a time series of asset prices (A_t), lease prices (L_t) and harvest data (Q_t). To these data we add a time series of output prices (F_t) and interest rates

(R_t) to form a data set for an empirical test of Arnason's theory. It is well-known that the application of classical regression analysis to time-series data may produce spurious results because of non-stationarity [10]. We use augmented Dickey–Fuller tests to determine the order of integration of each series and the autoregressive distributed lag (ADL) model described by Wickens and Breusch to take account of non-stationarity [13,25]. The general formulation of the asset price equation is

$$A_t = k_0 + \sum_{i=1}^{m} \alpha_i A_{t-i} + \sum_{j=1}^{r} \beta_j L_{t-j} + \sum_{j=1}^{r} \gamma_j Q_{t-j} + \sum_{j=1}^{r} \psi_j F_{t-j} + \sum_{j=1}^{r} \varphi_j R_{t-j} + \varepsilon_t. \tag{7}$$

In this form, the above model is ADL(m,r) where m and r are used to indicate the orders of the two polynomials in the lag operator. In the classical regression model $m=0$ and $r=0$. For period t, A_t is the asset price, k_0 the constant, L_t the lease price, Q_t the total allowable commercial catch, R_t the interest rate, and ε_t is assumed to be serially uncorrelated and homoscedastic [10].

Returning to Eq. (6) and bearing in mind the structure of New Zealand's QMS, it is clear that the annual TACC is potentially a significant policy instrument. We use a vector autoregression (VAR) model to trace out the effects of perturbing the TACC on asset price. Adjustments to the TACC are treated as an impulse and the VAR model enables us to study the response characteristics of asset price (A_t). The general form of a VAR model is

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B x_t + \varepsilon_t, \tag{8}$$

where y_t is the k vector of endogenous variables, x_t the d vector of exogenous variables, and $A_1, \ldots, A_p$ and B are matrices of coefficients.

5. Results

The econometric analysis proceeds in two stages. First, we provide estimates of Eq. (6) using classical regression and the ADL model [24]. Second, a VAR model is estimated to examine the convergence properties of asset prices to a TACC impulse.

5.1. Estimation

Two empirical specifications of Eq. (6) are based on the ADL model. First, we estimate a classical regression model ADL(0,0) based on levels of the variables. Second, we estimate the Wickens and Breusch [25] formulation ADL(1,1). Table 4 shows that the explanatory power of the ADL(0,0) model is reasonable, the signs consistent with theory but there is a strong presence of strong autocorrelation and the residuals are non-stationary. We then estimate an ADL(1,1) model and use the Newey–West correction method [10] that uses a heteroskedastic-consistent covariance matrix and an autocorrelation-consistent matrix to mediate the autocorrelation and derive stationary residuals. The signs are consistent with theory and are statistically significant.

Next, we estimate a five equation symmetric VAR model that enables us to generate an impulse response function that traces out the effect of a one-period, one standard deviation, shock to the

Table 4
Econometric models of asset price

	ADL(0,0)	ADL(1,1)
Variable	Coefficient	Coefficient
ΔA_t		0.463068
		(0.463068)
ΔL_t		-4.149598^{**}
		(1.04162)
L_t	5.928696^{**}	7.7037^{**}
	(1.109338)	(1.172211)
ΔQ_t		5.5695
		(4.5720)
Q_t	-16.15041^{**}	-14.5814^{**}
	(2.407804)	(2.3048)
ΔR_t		−111.823
		(1167.998)
R_t	−1328.435	−607.3497
	(818.1383)	(786.8567)
ΔF_t		-1923.80^{*}
		(986.7374)
F_t	4333.107^{**}	4295.702^{**}
	(661.4812)	(638.7909)
κ_0	66052.49^{**}	47364.92^{**}
	(14978.71)	(14890.09)
R^2 (adj. R^2)	0.82 (0.81)	0.88 (0.86)
DW	1.14	

Dickey–Fuller tests on residuals of ADL(1,1) model

Null hypothesis	Test statistic	Asy. Critical value 10%
Constant, no trend		
$A(1)=0$ T-test	−4.022	−2.57
$A(1)=A(1)=0$	8.135	3.78
Constant, trend		
$A(1)=0$ T-test	−4.224	−3.13
$A(1)=A(1)=0$	5.9914	4.03

TACC [10]. The shock will filter through the model to the extent that an adjustment to the TACC affects other endogenous variables. Only the estimation results for the asset price equation are described in Table 5. Likelihood ratio tests to evaluate the restrictions that the coefficients on the lags of Q (TACC) are statistically not different from zero show the TACC to influence price formation in the asset market. This outcome is consistent with the results of the ADL(1,1) estimation.

Fig. 1. shows the impulse response function. The TACC perturbation produces a sustained effect on asset price that takes about 100 months to dampen out and return to a stable

Table 5
VAR equation for asset price

Variable(lag)	Coefficient	Std error	t	p
$A(1)$	0.38462	0.1042	3.69	0
$A(2)$	0.38386	0.1021	3.76	0
$L(1)$	1.3393	0.9024	1.484	0.142
$L(2)$	0.68733	0.9154	0.7508	0.455
$Q(1)$	−5.2335	3.805	−1.376	0.173
$Q(2)$	3.3466	3.702	0.904	0.369
$F(1)$	425.89	822.8	0.5176	0.606
$F(2)$	1148.2	810.3	1.417	0.16
$R(1)$	−527.06	911.7	−0.5781	0.565
$R(2)$	851.76	937.6	0.9084	0.366
Constant	−6833.3	1.30E+04	−0.5277	0.599

$n=92$, system $R^2=0.99$, asset price equation $R^2=0.92$, likelihood ratio test that coefficients of Q are zero is rejected at $p=0.0025$.

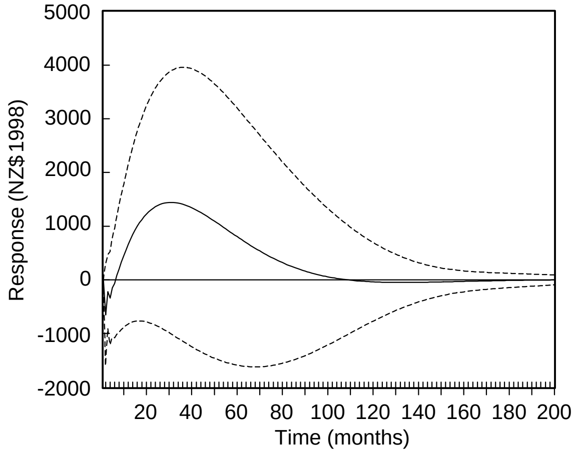

Fig. 1. Response of asset price to one standard deviation TACC innovation.

equilibrium. The response of asset price to an increase in the TACC is consistent with the ADL model. In the short-term the positive shock to the TACC ceteris paribus results in the asset price per tonne falling which, in turn, raises the annual return on asset price.

6. Discussion and conclusions

We have empirically tested Arnason's proposition that ITQ prices are functionally related to profit and that quota prices can be used to inform the fisheries management process. Econometric analysis of the time-series data from SNA 1 confirms Arnason's proposition. This result is significant because it suggests that a fisheries management agency can use quota prices to guide the setting of harvest limits.

The ADL(1,1) model provides a basis for estimating what the TACC ought to be given expectations in the fishery. Before working through an example, we want to reiterate two important caveats. The first proviso concerns Arnason's assumption about fisher homogeneity [3,12]. The second proviso relates to the dynamics inherent in fisheries management. One thing we can be certain about is that population dynamics, technology, and market prices, will change and there is no reason to expect the optimal TACC will be set in stone for ever. Rather, we see the above approach as being part of an ongoing monitoring and research effort that can inform management and the TACC setting process. The idea is not new and we point to the literature on feedback rules that use economic criteria to help set the TACC dating back to Clark and Munro [9]. Mathematical programming techniques also provide a basis for incorporating updated biological and economic information in the TACC setting process [18]. One major advantage of a rights-based system of management is that data are generated in the market for rights, by fishers facing market prices and operating with relatively good knowledge of stock productivity. Quota prices should reflect biological and economic conditions are they unfold over time.

Given the above caveats, we substitute the mean value for each variable other than Q into the estimated asset price equation to obtain a total rent function for the fishery:

$$QA = Q(116,119 - 14.48Q). \tag{9}$$

Using Eq. (9) we estimate the maximizing level of Q to be 3982 tonnes which falls at the lower end of the range 4150–7350 recommended by biologists in 1996 [2]. According to our model, reducing the TACC from its current level of 4500–3982 tonnes would increase the rent in SNA 1 by NZ$3.91 m. As a side issue, in 1995 the Ministry of Fisheries proposed to reduce the TACC to 3000 tonnes; industry argued for a TACC of 4000 tonnes. Litigation resulted in the TACC being held at 4938 until 1997 when it was reduced to 4500 tonnes. Industry's proposal of 4000 tonnes is remarkably close to our maximizing level of Q.

In addition to providing an estimate of the rent maximizing TACC we are also able to study the response of asset price to changes in the TACC. The Minister of Fisheries is required by law to move stocks toward B_{MSY} adjusted by economic conditions. The VAR model provides a framework for studying ex ante the response trajectory of asset and lease price to changes in the TACC. This opens up another opportunity for fisheries managers to study the economic impact of TACC adjustments and likely trajectories towards management targets. We would expect response trajectories to vary across fisheries, reflecting differences in stocks, technology, prices, management regime, and so on.

The above results also provide a basis for comparing the net benefits of allocating the TAC between commercial interests (TACC) and non-commercial interest (TNCC). If the marginal value of non-commercial harvest were known then fisheries managers could use the ADL model to consider the allowances made for recreational harvest vis-à-vis commercial harvest. Other applications are possible. For example, considerable cost-savings could follow from the use of econometric modeling as a partial substitute for the relatively more expensive biological approaches to setting limits to commercial harvest.

While the above results are encouraging we suggest that due consideration be given to the institutional structure that underpins the information generating mechanism. As noted earlier the QMS does not perfectly correspond to the rights-based system envisaged by Arnason [3].

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