Supply Response to North Atlantic Swordfish Quotas: Implications for Swordfish and Tuna Management

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ABSTRACT

In 1991, the National Marine Fisheries Service and, on a broader scale, the nations of the International Commission for the Conservation of Atlantic Tunas (ICCAT) placed multilateral restrictions on the harvest of swordfish from North Atlantic stocks.

These restrictions were necessary to reduce fishing mortality on the biologically overfished stocks. A general equilibrium simultaneous swordfish and tuna demand system is developed to predict potential price changes and estimate changes in consumer surplus. However, the supply response of unmanaged swordfish and tuna stocks to these price changes has significant economic implications for fishery managers and are addressed in this paper.

KEY WORDS: demand analysis, fisheries management, supply response, swordfish.

INTRODUCTION

The North Atlantic swordfish (*Xiphius gladius*) has recently been the subject of an increasing number of domestic and international regulatory measures. Emergency domestic regulations in the form of harvest quotas and an international agreement to limit swordfish harvest in the Atlantic are intended to rebuild the spawning stock to a level that will reduce the likelihood of recruitment failure. These new management initiatives are the result of an evaluation of the swordfish stocks by scientific panels, international negotiations, input from public hearings and management agency economic analyses (South Atlantic Fishery Management Council, 1985). Management measures such as harvest quotas can have significant economic or welfare effects upon swordfish consumers and producers. Additionally, changes in management not only affect harvest of North Atlantic swordfish but may also affect effort directed toward alternative species and alternative sources of swordfish. Swordfish and tuna fisheries are closely linked by gear types and by areas fished. These two species are also closely linked in the marketplace as their meat is similar in texture and product form. Thus, tuna is both a producer and consumer substitute and may be affected by changes in North Atlantic swordfish management.

Economic theory predicts that whenever two goods are substitutes in the marketplace, changes in the quantity demanded of one good are positively related to changes in the price of the substitute good. The imposition of a quota on North Atlantic swordfish will result in an increase in swordfish price from PS_1 to PS_Q (Figure 1). At higher swordfish prices, tuna becomes less expensive relative to swordfish and the quantity demanded of tuna increases from T_1 to T_2. As the market adjusts to the increased demand for tuna, the tuna price increases from PT_1 to PT_2 and quantities demanded decrease from T_2 to T_3 (note, however, that T_2 is still greater than T_1). The net effect of the harvest quota on swordfish is an increase in swordfish price, increased tuna price, and increased quantities of tuna demanded.

The potential effect of North Atlantic swordfish management on other swordfish stocks is illustrated in Figure 2. The aggregate amount of swordfish supplied to the United States (S_{TOTAL}) is the sum of all domestic Pacific and North Atlantic landings as well as imports from North Atlantic, South Atlantic, Pacific, or Mediterranean stocks. Under a pre-quota case, total swordfish supplied and demanded (Q_{US}) at price (P_{US}) is given by the intersection of the aggregate supply (S_{TOTAL}) and aggregate demand (D_{US}). Once a quota is placed on North Atlantic swordfish stocks, the supply curve for domestic landings and imports from North Atlantic stocks becomes vertical and the aggregate supply curve becomes the kinked curve S_{SR}. The price of swordfish now rises to P_{SR} and the quantity supplied to the domestic market is Q_{SR} in the short run. Under a quota, harvesters targeting North Atlantic stocks cannot respond to changes in market prices for swordfish but producers operating in the South Atlantic, Pacific, and Mediterranean can. The long run effect on prices and quantities of swordfish supplied to U. S. markets will depend upon the relative strength of the response to changes in swordfish prices by harvesters targeting these alternative swordfish stocks. Thus, North Atlantic swordfish management policy may have implications for effort directed toward unmanaged stocks.

Consideration of the potential collateral effects on substitute species and on alternative swordfish stocks should be an important component of fishery policy design. The objective of this paper is to report the results of a study in which these collateral effects were analyzed.

METHODS

Empirical Models

As part of a larger study (Bouchelle, 1992) to evaluate the consumer welfare changes due to harvest restrictions on North Atlantic swordfish stocks, a general equilibrium model of swordfish demand at the wholesale level was formulated. The structural equations of this system provide the basis for analyzing the effects of swordfish management on tuna fisheries.

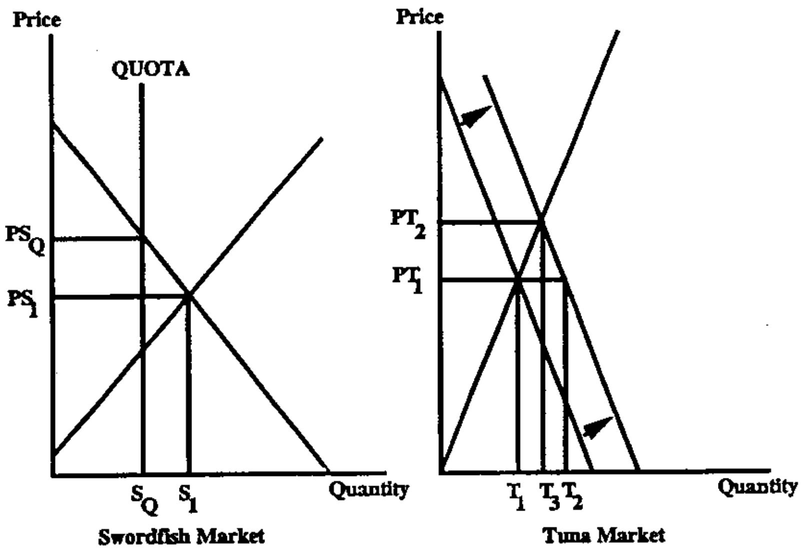

Figure 1. Effect of swordfish harvest restrictions on tuna markets.

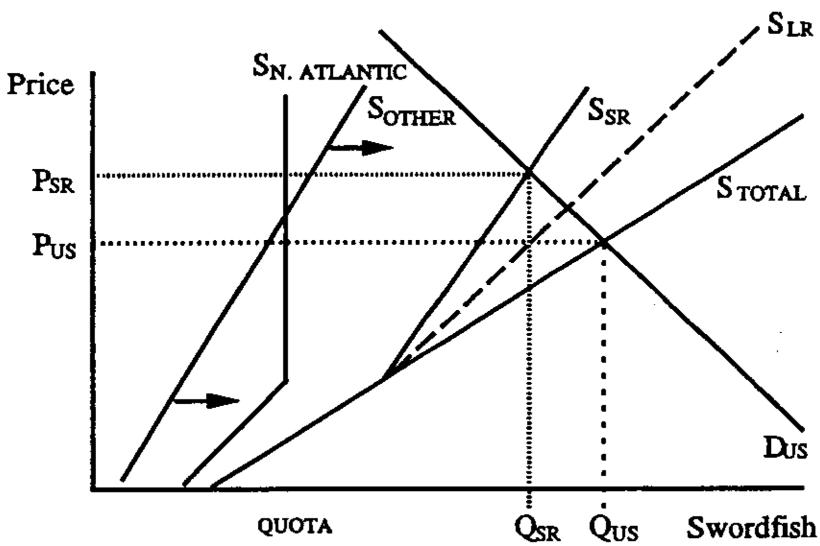

Figure 2. Supply response of alternative swordfish stocks to changes in swordfish price.

The two-equation demand system is:

$$\log P^{UST}_{SWt} = a_{10} + a_{11} \log Q^{UST}_{SWt} + a_{12} \log \hat{P}^{T}_{TUNt} + a_{13} \log Y_t \quad (1)$$

$$\log P^{T}_{TUNt} = a_{20} + a_{21} \log Q^{T}_{TUNt} + a_{22} \log \hat{P}^{UST}_{SWt} + a_{23} \log Y_t \quad (2)$$

where, P^{UST}_{SW} is nominal ex-vessel swordfish price, P^{T}_{TUN} is an index of nominal bluefin, bigeye and yellowfin ex-vessel tuna prices, Q^{UST}_{SW} is the total swordfish available in the U.S. (domestic + imports), Q^{T}_{TUN} is aggregate domestic bluefin, bigeye, and yellowfin tuna landings, and Y is real disposable personal income. The demand functions are specified as inverse demand functions. As such, the parameter estimates are interpretable as price flexibilities rather than the usual elasticities. A price flexibility measures the response in a commodity's price to changes in quantities demanded. In this case the cross-price flexibility of demand for tuna and swordfish is of particular interest. Since each demand function is specified in a double log form, the coefficients are directly interpretable as price flexibilities. If the estimated coefficient for Q^{UST}_{SW} is statistically significant then changes in quantities of swordfish will affect tuna price, and hence, harvest effort directed toward tuna.

To evaluate the effects of North Atlantic swordfish management on alternative sources of swordfish supply, a set of swordfish supply functions is specified. These supply functions are:

$$\log Q^{USA}_{St} = a_{30} + a_{31} \log P^{USA}_{SW\,t\text{-}2} + a_{32} \log C_{die} \quad (3)$$

$$\log Q^{AI}_{St} = a_{40} + a_{41} \log P^{AI}_{SW\,t} + a_{42}\, T \quad (4)$$

$$\log Q^{USP}_{St} = a_{50} + a_{51} \log P^{USP}_{SW\,t\text{-}2} + a_{52} \log C_{die} \quad (5)$$

$$\log Q^{OI}_{St} = a_{60} + a_{61} \log P^{OI}_{SW\,t\text{-}1} + a_{62}\, T \quad (6)$$

where Q^{USA} and P^{USA} are respectively U. S. domestic swordfish supply and price from the North Atlantic, Q^{AI} and P^{AI} are respectively U. S. imported supply and price from North Atlantic stocks, Q^{USP} and P^{USP} are respectively domestic supply and price from the Pacific, Q^{OI} and P^{OI} are respectively U. S. imported supply and price from all stocks other than the North Atlantic, C_{die} is a price index for diesel fuel, and T is a trend variable. The cost of diesel fuel is used as a supply shifter for the domestic Pacific and North Atlantic supply functions. Equivalent data were not available for importing countries so the trend variable is included to capture shifts in supply due to changes in fishing costs caused by fluctuations in stock abundance. Quantities of imported product are hypothesized to respond to changes in current prices, whereas domestic landings respond to lagged prices. This would support the argument that swordfish longliners make long term decisions to fish for certain species and that the amount of effort they expend in a given season is determined by prices in the past season or at the beginning of the present season. Since each function is estimated in double-log form, the resulting parameter estimates are directly interpretable as supply elasticities.

For purposes of this paper, the coefficients of interest are the own-price elasticities of supply (P^{USA}, P^{AI}, P^{USP}, and P^{OI}). In each case the own-price elasticities are hypothesized to be positive reflecting the positive relationship between price and quantities supplied. The magnitude of each estimated elasticity is of particular relevance because it provides a measure of the relative strength of the response to changes in swordfish prices.

RESULTS

To estimate the specified demand system and the supply functions, a quarterly time series from 1984-1990 was constructed. A dummy variable for each of the first three quarters in each year was added to each function to account for any seasonality in swordfish demand and supply. The demand system was estimated using two-stage least squares regression procedures while the supply functions were estimated using ordinary least squares (Maddala, 1977). In each case a correction for first-order serial correlation was conducted (Pindyck and Rubinfeld, 1981). The results for the analysis of the swordfish and tuna demand system are presented in Table 1 and the results of the analysis of swordfish supply functions are reported in Table 2.

The coefficients of interest in Table 1 are denoted by underscoring. The statistical results show that tuna demand is affected by changes in swordfish supplied to the market. The cross-price flexibility of tuna for swordfish is positive and significant. The cross-price flexibility indicates that a one percent change in swordfish prices will result in a 0.84 percent increase in tuna price. This price increase is likely to induce an increase in harvest effort directed toward tuna species. Depending upon the magnitude of this effort response increased attention may need to be given to tuna fishery management.

Of the estimated own-price supply elasticities, only the coefficient for the supply elasticity from imported swordfish from outside the North Atlantic management unit is statistically significant. However, both point estimates of the elasticity of supply of swordfish from sources outside the North Atlantic show a near unitary supply response. Thus, a one percent change in swordfish price would be predicted to induce an approximately equal percentage change in swordfish supplied from the U.S. domestic Pacific region or imported from outside the North Atlantic. In fact, domestic landings of swordfish from the Pacific region have nearly doubled since the imposition of the North Atlantic harvest restrictions (National Marine Fisheries Service, 1992). To attribute this

Table 1. Estimated coefficients for swordfish and tuna demand system.

VARIABLE	SWORDFISH	TUNA
Intercept	-7.194	-37.890*
Swordfish Price[a]		0.840
Tuna Price	0.008	
Total Swordfish Quantity	-0.555*	
Total Tuna Quantity		-0.626*
Income	2.137*	5.998*
Quarter One	0.234*	0.106
Quarter Two	-0.083	0.017
Quarter Three	0.172*	0.872

[a] = swordfish price associated with each column heading.
* = statistically significant at the .05 level.

Table 2. Estimated coefficients for swordfish supply functions.

Variable Domestic	Imported North Atlantic	Domestic North Atlantic	Imported Pacific	Other Sources
Intercept	12.653*	16.325*	11.211*	12.377*
Swordfish Price[a]	0.434	0.165	0.966	0.924*
Diesel Index	0.229	0.357		
Trend	-0.061	0.033		
Quarter One	-0.569*	-0.674*	-2.064*	0.756*
Quarter Two	-0.084	-0.829*	-2.699*	1.208
Quarter Three	0.460*	0.476*	-0.814*	0.612*

[a] = swordfish price associated with each column heading.
* = statistically significant at the .05 level.

large increase in Pacific landings solely to the change in North Atlantic swordfish management policy would overstate its effect. However, the statistical results do indicate that changes in swordfish price resulting from changes in North Atlantic swordfish policy actions will affect harvest effort directed toward alternative swordfish stocks. This redirection of effort to alternative stocks may lead to the subsequent need for management of these alternative swordfish stocks.

CONCLUSIONS

Management of North Atlantic swordfish stocks was prompted by concern over the fact that although North Atlantic swordfish landings were increasing in volume, the average weight per fish was declining. To counteract this problem, management measures were enacted that placed restrictions on the harvest of North Atlantic swordfish. In this study it was hypothesized that these management measures could have unintended effects on effort directed toward substitute species and alternative swordfish stocks. The results of the statistical model reported herein support these hypotheses. Changes in swordfish prices were shown to affect tuna markets and hence, the amount of effort directed toward tuna. Changes in swordfish prices were also shown to induce increased harvest effort directed toward swordfish stocks in the Pacific and other unmanaged swordfish stocks. The full extent of these unintended effects is not known at this time. Nevertheless, the analytical results indicate that these effects can occur, and that they may be significant. Therefore, prudent fishery policy analysis should consider both the intended and unintended effects of implementing changes in fishery management regulations.

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