NOAA Technical Memorandum NMFS-PIFSC-20

September 2009

Demand for Hawaii Bottomfish Revisited: Incorporating Economics into Total Allowable Catch Management

Justin Hospital
Minling Pan

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

About this document

The mission of the National Oceanic and Atmospheric Administration (NOAA) is to understand and predict changes in the Earth's environment and to conserve and manage coastal and oceanic marine resources and habitats to help meet our Nation's economic, social, and environmental needs. As a branch of NOAA, the National Marine Fisheries Service (NMFS) conducts or sponsors research and monitoring programs to improve the scientific basis for conservation and management decisions. NMFS strives to make information about the purpose, methods, and results of its scientific studies widely available.

NMFS' Pacific Islands Fisheries Science Center (PIFSC) uses the **NOAA Technical Memorandum NMFS** series to achieve timely dissemination of scientific and technical information that is of high quality but inappropriate for publication in the formal peer-reviewed literature. The contents are of broad scope, including technical workshop proceedings, large data compilations, status reports and reviews, lengthy scientific or statistical monographs, and more. NOAA Technical Memoranda published by the PIFSC, although informal, are subjected to extensive review and editing and reflect sound professional work. Accordingly, they may be referenced in the formal scientific and technical literature.

A **NOAA Technical Memorandum NMFS** issued by the PIFSC may be cited using the following format:

Hospital, J., and M. Pan.
2009. Demand for Hawaii bottomfish revisited: incorporating economics into total allowable catch management. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-PIFSC-20, 19 p. + Appendix.

For further information direct inquiries to

Chief, Scientific Information Services
Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
2570 Dole Street
Honolulu, Hawaii 96822-2396

Phone: 808-983-5386
Fax: 808-983-2902

Cover: *Fish on Fire*, copyright 2008 Joseph R. McAuliffe; www.ZenGyotaku.com

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Demand for Hawaii Bottomfish Revisited: Incorporating Economics into Total Allowable Catch Management

Justin Hospital
Minling Pan

Pacific Islands Fisheries Science Center
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii 96822-2396

NOAA Technical Memorandum NMFS-PIFSC-20

September 2009

EXECUTIVE SUMMARY

Successful fishery management decisions in the future will require consideration of economic interrelationships as well as biological ones. This research presents a generalized inverse demand system, as applied to the Hawaii bottomfish fishery, and details market linkages between various fish species in the Hawaii bottomfish market. Additionally, we estimate measures of consumer welfare changes associated with a variety of potential total allowable catch (TAC) levels for main Hawaiian Islands (MHI) Deep 7 bottomfish species. Monthly State of Hawaii commercial data and National Marine Fisheries Service foreign trade data from 1996 to 2006 are used to formulate the demand system.

Our demand estimates show that Hawaii bottomfish prices are rather price elastic and, therefore, not very responsive to own-quantity changes, which means that any price increases seen from reductions in quantities may still translate to declines in total revenues. Likewise, increases in MHI Deep 7 TAC levels may not necessarily lead to increased fishery revenues due to decreased prices. However, consumers will benefit from increases in total allowable catch levels, through lower prices, at the expense of conservation concerns. These findings complicate the task of fishery managers to balance conservation with economic considerations.

We found that scale effects dominate substitution effects for our demand system. This indicates that the aggregate market supply plays a large role in price determination for the Hawaii bottomfish fishery. We find all species in our demand system to be substitutes in the marketplace implying that MHI Deep 7 TAC decisions may have economic ‘spillover’ effects. For example, any potential reductions in TAC levels for MHI Deep 7 species may translate to increased demand for other domestic species as well as imports. This could have the unintended consequence of increased prices for non-regulated species and subsequently may lead to increased fishing pressure on these stocks. Accordingly, biological indicators for non-regulated and substitute species should be closely monitored along with those for the regulated stocks.

CONTENTS

INTRODUCTION 1

THE HAWAII BOTTOMFISH FISHERY 1

LITERATURE REVIEW 4

ECONOMETRIC MODEL 5

PRICE FLEXIBILITY DERIVATION 6

WELFARE 7

DATA DESCRIPTION 8

EMPIRICAL RESULTS 10

PRICE FLEXIBILITIES OF BOTTOMFISH SPECIES 10

Compensated Own-Price Flexibility 11

Compensated Cross-Price Flexibility and Allais Coefficients 12

Scale Flexibility 13

Uncompensated Price Flexibility 14

WELFARE EFFECTS OF MHI DEEP 7 TAC MANAGEMENT 14

SEASONALITY AND MACROECONOMIC CONDITIONS 15

CONCLUSIONS 16

REFERENCES 18

APPENDIX A-1

INTRODUCTION

The reauthorized Magnuson-Stevens Fishery Conservation and Management Act (2007) mandates the establishment of catch quotas for all federal fisheries by 2011. This regulatory tool has a direct effect on fishers, in terms of landings and revenues, but also has implications for consumers and downstream firms as ex-vessel price variations, caused by management actions, travel through the market chain. There are also ecosystem effects of this regulatory structure, as quota levels may shift fishing effort to non-regulated species and consumer demand may lean towards species substitutable in the marketplace. Additionally, in the modern globalized economy, domestic regulations offer opportunities for foreign producers to contribute to domestic markets in attempts to satisfy market demand.

In the case of the Hawaii bottomfish fishery, stock assessment scientists are able to advise fishery managers of the biological implications of total allowable catch (TAC) management in terms of the risk to overfishing and biomass levels (Brodziak, et al., 2009). However, the economic implications of this new management regime are poorly understood. A challenge inherent in assessing the economics of fishery management regulations is that the benefits from fisheries regulations often come from future increases in the health of fish populations, while the costs come from the current reductions in quantities harvested. The role of economics in the context of ecosystem management is to provide information to help allocate scarce resources to produce desired states of nature consistent with the societal goal of maintaining a level of ecosystem health and resilience (Wagner et al., 1998). Successful fishery management decisions require considerations of economic interrelationships as well as biological ones. However, fishery managers currently do not have adequate estimates of the demand structure within the Hawaii bottomfish fishery, as the sole existing demand analysis in the literature was conducted more than two decades ago (Pooley, 1987). This research introduces a generalized inverse demand system, as applied to the Hawaii bottomfish fishery, to determine the market linkages among various fish species in the Hawaii bottomfish market and explore economic considerations for TAC management.

The Hawaii Bottomfish Fishery

The Hawaii bottomfish management complex is made up of 15 species of snappers, groupers, and jacks[1]. While the bottomfish fishery is much smaller than the pelagic fisheries in the region, it is comparably rich in tradition and cultural importance. Most of the bottomfish harvested in Hawaii are red, a color considered symbolic of good luck and, thus, are of high cultural significance during the winter holiday season as well as celebrations such as birthdays, graduations, and weddings. The bottomfish fishery is also important to the tourist industry in the islands as a source of fresh bottomfish served at restaurants across the State of Hawaii.

Bottomfish fishing is conducted throughout the Hawaiian Archipelago, with management of the fishery historically delineated by three zones: the main Hawaiian Islands (MHI) and the limited-entry Mau and Ho’omalu Zones in the Northwestern Hawaiian Islands (NWHI)[2]. The Hawaii bottomfish fishery experienced steady growth throughout the 1970s into the 1980s, with market supply peaking in 1987 at nearly 1.8 million pounds, valued at nearly $9.3 million (in 2008 dollars).

---

[1] For a complete list of Bottomfish Management Unit Species (BMUS), see Section A1 in the Appendix.

[2] An area of approximately 1200 square miles, located northwest of Kaua’i.

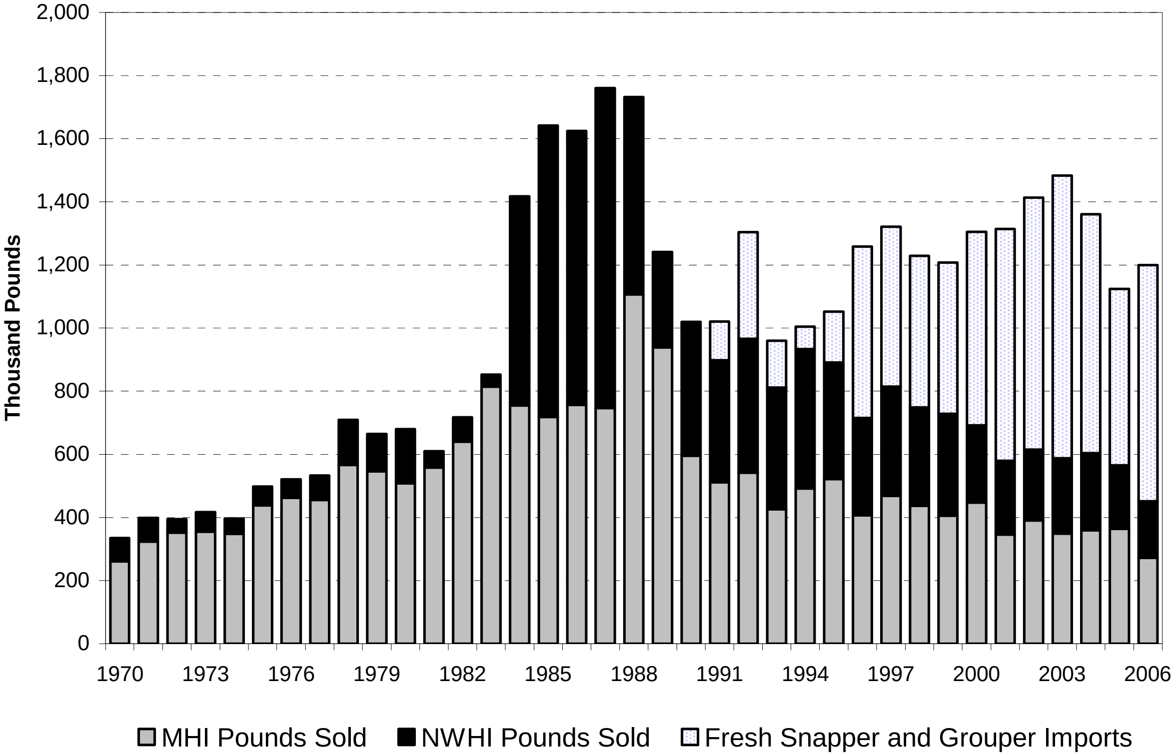

Figure 1.—Hawaii bottomfish market: domestic pounds sold and fresh snapper and grouper imports, 1970–2006.

While the past 20 years have seen steady declines in domestic supply and revenues, the total size of the Hawaii bottomfish market has held relatively stable over the past decade (Table 1). As evident in Figure 1, the bottomfish market has increasingly relied on fresh snapper and grouper imports from the South Pacific to satisfy market demand in recent years. Fresh snapper and grouper imports comprised approximately 62% of the total bottomfish market in 2006, a historic high. These trends have important implications for domestic prices and revenues, as the increasing role of imports may be distorting traditional demand and supply relationships within the fishery.

Table 1.—Hawaii bottomfish market composition (pounds) and domestic revenues (in 2008 dollars), 1970–2006.

Year	Domestic Pounds Sold (1000s)	MHI Pounds Sold (1000s)	NWHI Pounds Sold (1000s)	Fresh Snapper and Grouper Pounds Imported (1000s)	Imports Percentage of Total Market	Total Domestic Revenues ($1000s)
1970	335	261	74	-	-	$1,395
1971	398	323	75	-	-	$1,653
1972	395	352	43	-	-	$1,878
1973	417	355	62	-	-	$2,053
1974	397	348	49	-	-	$1,871
1975	497	438	59	-	-	$2,374
1976	521	462	59	-	-	$2,684
1977	533	455	78	-	-	$2,816
1978	709	566	143	-	-	$3,763
1979	665	547	118	-	-	$3,459
1980	680	508	172	-	-	$2,983
1981	610	558	52	-	-	$3,150
1982	717	640	77	-	-	$3,767
1983	853	815	38	-	-	$4,554
1984	1417	755	662	-	-	$7,058
1985	1641	718	923	-	-	$8,257
1986	1625	757	868	-	-	$8,280
1987	1760	747	1013	-	-	$9,336
1988	1732	1107	625	-	-	$9,019
1989	1241	939	302	-	-	$6,876
1990	1019	596	423	-	-	$5,586
1991	898	511	387	122	0.12	$4,429
1992	966	542	424	338	0.25	$4,720
1993	811	426	385	149	0.15	$3,930
1994	934	491	443	70	0.07	$4,559
1995	891	522	369	161	0.15	$4,015
1996	715	406	309	543	0.43	$3,534
1997	815	469	346	507	0.38	$3,801
1998	748	437	311	481	0.39	$3,296
1999	728	406	322	480	0.40	$3,296
2000	692	447	245	613	0.47	$3,310
2001	580	346	234	734	0.56	$2,557
2002	615	390	225	798	0.57	$3,002
2003	588	349	239	895	0.60	$2,841
2004	604	359	245	757	0.56	$3,042
2005	565	364	201	559	0.50	$2,940
2006	451	272	179	749	0.62	$2,222

Much of the decline in domestic production can be accounted for by the institution of a limited-entry management regime in the NWHI during the early 1990s and reductions in fishing participation (vessels and trips) fleet-wide. Moreover, fishing mortality for bottomfish has been excessive in the MHI (Moffitt et al., 2006), leading the Western Pacific Regional Fishery Management Council to enact an emergency seasonal closure for the summer of 2007, coupled with a TAC management regime applied to the MHI Deep 7[3] bottomfish complex. In addition to this management challenge in the MHI, by order of Presidential Proclamation 8031, signed in June 2006, the Northwestern Hawaiian Islands Marine National Monument[4] was established in the NWHI, which means that all extractive activity is prohibited in this region. This includes a phase out of the active NWHI bottomfish fishery. Thus, by 2011, the NWHI zone of the Hawaii bottomfish fishery will be closed. This historically represents, on average, approximately 35% of domestic bottomfish brought to the Hawaii market.

In light of recent domestic-fishing conditions, fresh snapper and grouper import trends, and the impending NWHI fishery closure, it seems vital to revisit demand considerations within the fishery to explore the economic implications of the newly instated total allowable catch management regime within the fishery. This research seeks to revisit existing bottomfish demand research using recent data and methodological advances to assess the current demand structure for Hawaii bottomfish. The analysis of demand for fish has numerous important implications for policy design and fisheries management. For example, it allows us to examine the potential for ‘spillover’ pricing effects to unregulated stocks as a result of TAC management and allows managers to design policy with consideration of economic tradeoffs. Also, with demand estimates, the consumer and processor costs of harvest reductions and the future benefits of stock increases could be calculated accurately (NOAA, 1992).

LITERATURE REVIEW

There is only one published demand analysis for the Hawaii bottomfish fishery, that of Pooley (1987). Pooley (1987) estimated short-term and long-term price effects from changes in quantities using single-equation inverse demand models. He found low short-term price flexibilities, strong seasonality effects, and weak substitutability between bottomfish species groups. However, the data he used, for the 1965–1982 period, are less relevant for today’s management regime. Additionally, the Pooley (1987) analysis was completed at the historic peak of the domestic fishery, and imports had yet to become prevalent in the marketplace. The Hawaii bottomfish market is fundamentally different today.

A problem with the single equation modeling framework used by Pooley (1987) is that it does not account for market interrelationships among species that may be closely related in consumption and pricing. As a result, estimates of economic gains and losses associated with changes in allowable catch or other management proposals are biased (Holt and Bishop, 2003).

To address the underlying issues of single-equation models, researchers have adopted a systems framework in the estimation of fish demand and market analysis. By establishing a systems framework, the analyst is better equipped to handle multiple species and determine substitution effects. An important aspect of multi-equation or systems models is that they are useful for determining ‘spillover’ effects of policy actions, even if the policies themselves are implemented on a single-species basis (Holt and Bishop, 2003). Strengthening a harvest restriction on one species may have implications for prices

---

[3] This consists of six deepwater snapper (onaga, ‘ōpakapaka, ehu, gindai, kalekale, lehi) and a species of grouper (hāpu’upu’u).

[4] Renamed the Papahānaumokuākea Marine National Monument in 2007.

of other species. Through built-in, cross-equation substitution effects, consistent with microeconomic theory, researchers are better able to account for such unintended consequences of fisheries management.

The literature has matured greatly in recent years, and examples of inverse demand systems as applied to fisheries are becoming common (Eales et al., 1997; Holt and Bishop, 2002; Hilmer et al., 2004; Park et al., 2004; Lee, 2007; Lee and Kennedy, 2008). These researchers have all tackled the application of generalized inverse demand system estimation. Of particular interest to this research are findings in the Gulf of Mexico snapper and grouper fisheries (Park et al., 2004). Park et al. (2004) estimated a synthetic inverse demand system to analyze demand substitution relationships for the snapper/grouper complex in the Gulf of Mexico. In addition, they calculated welfare estimates of hypothetical harvest reductions. They found little measured effect on prices from regulatory measures, suggesting that market prices are good per-unit measures of the welfare costs of catch reductions to consumers (Park et al., 2004). This study follows recent methodological developments in the literature to revisit demand considerations for the Hawaii bottomfish fishery.

ECONOMETRIC MODEL

Brown et al. (1995) were able to nest four popular inverse demand systems (Inverse Rotterdam Demand System (IROT), Inverse Almost Ideal Demand System (IAIDS), Inverse Census Bureau of Statistics (ICBS), Inverse National Bureau of Research (INBR)) into a generalized inverse demand system specification[5] as follows:

$$w_i d\ln p_i = \sum_{j=1} \pi_{ij} d\ln q_j + \pi_i d\ln Q - \theta_1 w_i d\ln Q - \theta_2 w_i d\ln(q_i / Q) \qquad (1)$$

where

$w_i =$ budget expenditure share of species *i*
$p_i =$ normalized price for species *i*
$q_j =$ monthly quantities for species *j*
$Q =$ Divisia volume index (reflecting aggregate market size)
$\theta_1, \theta_2 =$ nesting (mixing) parameters
$\pi_{ij} =$ substitution parameters
$\pi_i =$ scale parameters

and $\pi_{ij}, \pi_i, \theta_1, \theta_2$ are estimated parameters.

This system reduces to each individual demand system (IROT, IAIDS, ICBS, INBR) based on the configuration of the estimates for the θ_1 and θ_2 mixing parameters. For example, an estimation where $\theta_1 = 0$ and $\theta_2 = 0$ the system reduces to the IROT specification. Likewise, a configuration of $\theta_1 = 1$ and $\theta_2 = 1$ would correspond to the IAIDS model. As shown in Table 2, the ICBS and INBR are

---

[5] For details on the underlying theoretical framework of this specification, see Section A2 in the Appendix.

hybrid models. This is advantageous as a priori; theory gives little guidance towards choosing an appropriate functional form for demand specification. In essence, using a generalized model we allow the data to select the most appropriate functional form.

Table 2.—Nested model restriction matrix.

Model	IROT	IAIDS	ICBS	INBR
θ_1	0	1	1	0
θ_2	0	1	0	1

Based on strong seasonality aspects of the fishery, we include monthly dummies, $\sum_{k=1}^{11}\delta D_{kt}$, with December as the base. Additionally, following Lee and Kennedy (2008), this study modifies the specification to reflect the discrete-time nature of the data, and the $\bar{w}_{it}$ term, the 2-year moving average in the budget expenditure share of good *i*, is used to avoid a simultaneity problem. Our final empirical specification, a Differential Generalized Inverse Demand System (DGIDS), is as follows:

$$\bar{w}_{it}\Delta \ln p_{it} = \alpha_i + \sum_{k=1}^{11}\delta D_{kt} + \sum_{j=1}^{6}\pi_{ij}\Delta \ln q_{jt} + \pi_i \Delta \ln Q_t - \theta_1 \bar{w}_{it}\Delta \ln Q_t - \theta_2 \bar{w}_{it}\Delta \ln(q_{it} / Q_t) + \varepsilon_{it} \tag{2}$$

$$\text{where } \Delta \ln Q_t = \sum_{j=1}^{6}\bar{w}_{jt}\ln q_{jt}\ ,\ \bar{w}_{it} = \frac{w_{it} + w_{it-1}}{2}\ ,\ \text{and } \Delta \ln p_{it} = \ln p_{it} - \ln p_{it-1}$$

The features required of a robust inverse demand system are the following: (i) the price is endogenous and quantity is exogenous (ii) the system of equations of endogenous prices is expressed using budget shares, which then leads to the adding up of the system equations, and (iii) the mathematical form of variables in the system of equations is that of differential logarithms (Lee and Kennedy, 2008). Clearly, the latter two of these features are present in Equation 1. For our estimation, the quantities are treated as exogenous, and their covariance with current and lagged disturbance terms is taken to be zero. Under these assumptions, the generalized model (Equation 2) and its nested submodels can be estimated consistently using the generalized least squares estimator or, equivalently, the Seemingly Unrelated Regression (SUR) estimator (Park et al., 2004). The assumption of predetermined (exogenous) quantities and endogenous prices was assessed using a Wu-Hausman test and the results confirmed exogeneity in quantities and endogeneity in prices[6].

Price Flexibility Derivation

Price flexibilities are an important finding in understanding the market interrelationships of fish species. The price flexibility, which measures the percentage change in price given a percentage change in quantities, is the inverse demand analogue to traditional demand elasticities. These estimates shed light on the substitutability of species and allow researchers to assess the pricing implications of management actions, which often take the form of supply-side measures. To estimate quantity effects on price, our study estimates scale and Antonelli substitution coefficients (own and cross-price flexibilities).

It is important to understand the pricing implications of own-quantity changes. The compensated own-price flexibility will detail how prices will respond to a percentage own-quantity change. The term

---

[6] For details concerning empirical model specification, see Section A3 in the Appendix.

‘compensated’ refers to the fact that this measure is utility-theoretic as it is estimated from the unobserved Hicksian demand curve (where utility is held fixed). The DGIDS own-price flexibility is calculated as:

$$f_{ii}^{*} = \pi_{ij} / w_i - \theta_2 + \theta_2 w_i \tag{3}$$

Subsequently, in determining the degree of substitutability between various species in the marketplace and to measure potential policy ‘spillover’ effects, we derive the compensated cross-price flexibility. In the DGIDS framework the compensated cross-price flexibility is calculated as:

$$f_{ij}^{*} = \pi_{ij} / w_i + \theta_2 w_j \tag{4}$$

The scale flexibility relates the individual species *i* to the aggregate market. It would suggest the percentage change in the price of species *i* given a percentage change in aggregate market supply, all else held constant. Based on our DGIDS specification, the scale flexibility is calculated as:

$$f_i = \pi_i / w_i - \theta_i \tag{5}$$

Additionally, we present uncompensated flexibilities. Contrary to compensated flexibilities, uncompensated flexibilities are calculated from observed, or Marshallian demand curves. Thus, these are not utility-theoretic measures but can be useful because they approximate the combination of the substitution and scale effects brought on by a change in quantities. The uncompensated cross-price flexibility can be derived from the Antonelli equation (the inverse demand equivalent of the Slutsky equation). Empirically, we estimate the uncompensated cross-price flexibilities using estimated compensated flexibilities and the scale flexibility:

$$f_{ij} = f_{ij}^{*} + w_j f_i \tag{6}$$

Welfare

Consumers derive satisfaction when purchasing goods. When quantities change, consumers and downstream firms may benefit or suffer based on the resultant change in market prices. Economists term this change in satisfaction a welfare change[7]. The degree of this change depends on estimated price and scale flexibilities. The compensating variation measure asks what compensating payment (that is, an offsetting change in income) is necessary to make an individual indifferent to the original situation and the new price set (Freeman, 2003). For an increase in quantities, consumers and downstream firms benefit from decreased prices, and the estimated compensation variation value will be greater than zero. This corresponds to a willingness to pay to obtain the lower prices. Likewise, for a decrease in quantities, consumers will suffer in the face of higher prices, as reflected in a negative compensating variation value. We calculate the compensating variation, using our estimated compensated price flexibilities, as follows:

$$\mathit{Compensating\ Variation} = \Delta q \left[p^0 + 0.5(f_{ii}^{*}) \left(\frac{p^0}{q^0} \right) \Delta q \right] \tag{7}$$

where p^0 is the original price, q^0 is the original quantity level, and Δq is the proposed or actual change in quantity levels. We can use this to calculate the welfare changes to consumers and downstream firms associated with changes in MHI Deep 7 TAC levels.

---

[7] For a more in-depth summary of welfare, consult Section A2 of the Appendix.

DATA DESCRIPTION

The demand system for this analysis is a subset of the total Hawaii seafood market, and its definition is limited to domestic bottomfish, domestic reef fish, and fresh snapper and grouper imports. Of particular interest to this analysis are the Deep 7 bottomfish species. Six deepwater snappers (onaga, ‘ōpakapaka, ehu, gindai, kalekale, lehi), and a species of grouper (hāpu’upu’u) comprise the Deep 7 management complex and are the most desired local bottomfish species. The Deep 7 species comprise a significant portion of the total Bottomfish Management Unit Species (BMUS) catch; thus, in light of data limitations, they serve as a proxy for overall BMUS stock health. In recent years (2002–2006), while the Deep 7 species have accounted for approximately 61% of total BMUS landings, they represent 77% of total bottomfish revenues. Reef fish[8], for this analysis, include many commercially important species such as akule (*Selar crumenophthalmus*) and opelu (*Decapterus macarellus*), and species groups such as goatfish, and parrotfish, amongst others. In 2006, this demand system accounted for approximately 2.5% of Hawaii seafood volume and 5.7% of fishery revenues for the State of Hawaii[9].

For this analysis we employ monthly data and a 1996–2006 study period. Our data set is built using a variety of sources, including the State of Hawaii Division of Aquatic Resources (DAR) Fishermen Reporting System, the State of Hawaii Seafood Dealer Database, and the Northwestern Hawaiian Islands Fishing Reports. Fresh snapper and grouper import data are obtained from the NMFS Foreign Trade Database, which is made up of data from the U.S. Customs Office.

Table 3.—Monthly Quantity Share Data Summary 1996–2006.

Fish Group	Sample Average Quantity Share (%)	Average Quantity Share in 1996 (%)	Average Quantity Share in 2006 (%)	Minimum Monthly Qty (lbs)	Maximum Monthly Qty (lbs)
MHI Deep 7	10.2	11.3	9.2	3,665	59,764
NWHI Deep 7	6.8	6.9	4.3	1,309	30,303
Imports	27.7	21.6	39.6	19,176	95,218
Uku	5.4	4.5	7.6	2,532	23,788
Other BMUS	3.5	3.9	1.9	1,295	21,513
Reef fish	46.4	51.8	37.4	33,865	195,788

As evident in Table 3, there have been fundamental changes in the species composition of the Hawaii bottomfish market in recent years, with declines in domestic Deep 7, other BMUS and reef fish being filled by a large influx of fresh snapper and grouper imports and a modest increase in uku quantity shares. We treat uku separately in our demand system because of its relatively high quantity share and its unique role in bottomfish management. Seasonal demand and fishing effort for uku peak during the summer months and are not included in the current TAC management regime.

---

[8] Reef fish species groups included for this analysis are the following; Bigeye Scad, Emperors, Goatfish, Groupers, Jacks, Mullet, Parrotfish, Rudderfish, Snappers, Surgeonfish, Squirrelfish, and Wrasse.

[9] This demand system excludes the overwhelmingly dominant pelagic market species for two reasons. One, it seems that the current demand system specification is the most relevant and applicable to management of the Hawai’i bottomfish fishery. Secondly, there is a fundamental lack of understanding of the true size of the pelagic market as a result of the prevalence of transshipments of imported and domestically (non-Hawai’i) caught pelagic species into Honolulu, for which data do not exist. Inclusion of these pelagic species data would be a clear underestimation. Consideration of pelagic species is left for future research.

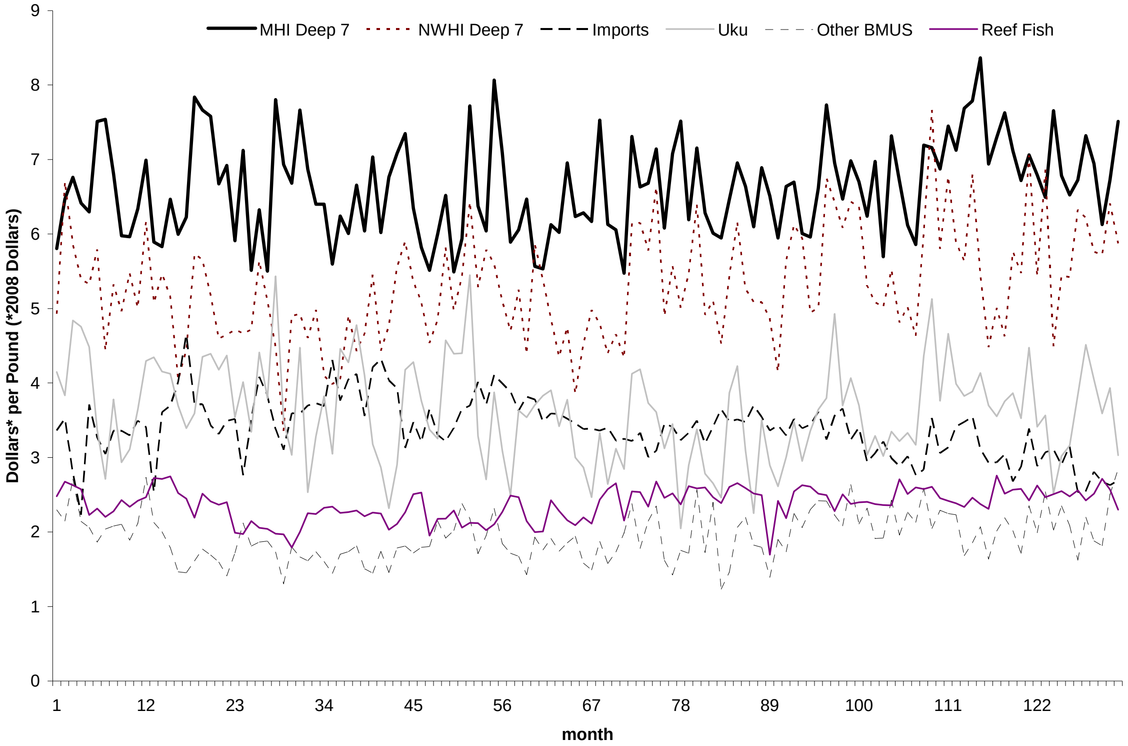

Figure 2.—Price* trends, 1996—2006 (*all prices expressed in 2008 dollars).

There is a fairly rigid ex-vessel price hierarchy in the Hawaii bottomfish fishery. The Deep 7 species command higher prices than uku, other bottomfish, and reef fish (see Figure 2 and Table 4). Most bottomfish from the MHI receive a premium over NWHI bottomfish because of quality concerns. The typical MHI bottomfish trip is a single day trip, with the occasional multiday trip (2–3 days); NWHI trips can last upwards of 2 weeks, so their catch generally is not as fresh. Additionally, domestic Deep 7 species command nearly double the price of their foreign counterparts. As shown in Figure 2, there is a highly seasonal component to bottomfish price formation. Based on cultural considerations, demand for domestic Deep 7 fish peaks in December, around the Christmas and New Year's (Western) holidays. There has been relatively low variation in real bottomfish prices over the past decade, as shown in Figure 2 and Table 4.

Table 4.—Monthly price (2008 dollars) data summary 1996–2006.

Fish Group	Sample Average Monthly Price ($/lb)	Average Monthly Price in 1996 ($/lb)	Average Monthly Price in 2006 ($/lb)	Minimum Average Monthly Price ($/lb)	Maximum Average Monthly Price ($/lb)
MHI Deep 7	6.62	6.89	6.57	5.48	8.36
NWHI Deep 7	5.30	5.91	5.44	3.36	7.66
Imports	3.39	2.86	3.24	2.23	4.66
Uku	3.62	3.60	3.83	2.04	5.44
Other BMUS	1.93	2.18	2.18	1.24	2.84
Reef fish	2.37	2.51	2.42	1.69	2.75

During the study period, the bottomfish market has seen changes in expenditure shares composition. Given relative stability in real (inflation-adjusted) prices, these changes are primarily in response to fluctuations in landed quantities. While the combined domestic Deep 7 species (MHI and NWHI) account for approximately 17% of quantity share landings (Table 3), they comprise just over 30% of average monthly expenditure share in our demand system (Table 5). The seasonal aspect of the bottomfish fishery is verified when one considers the range in minimum and maximum monthly expenditure shares.

Table 5.—Monthly budget share data summary 1996–2006.

Fish Group	Sample Average Share of Total Monthly Expenditure (%)	Average Expenditure Share in 1996 (%)	Average Expenditure Share in 2006 (%)	Minimum Monthly Expenditure Share (%)	Maximum Monthly Expenditure Share (%)
MHI Deep 7	19.5	22.2	19.2	5.7	49.6
NWHI Deep 7	10.7	11.4	7.6	1.3	21.0
Imports	28.1	21.1	34.9	9.1	50.1
Uku	5.8	4.9	8.1	1.4	17.3
Other BMUS	2.1	2.6	1.3	0.5	4.8
Reef fish	33.8	37.8	28.9	14.3	53.9

EMPIRICAL RESULTS

We now detail the results of our demand system estimations[10]. This section will show empirically estimated price flexibility estimates and Allais coefficients, the latter being an alternative measure of market interrelatedness. It will conclude with an application of the price flexibility estimates to practical management issues in the Hawaii bottomfish fishery, specifically exploring the consumer welfare implications of changes in main Hawaiian Islands Deep 7 TAC levels and the use of seasonal closures as a management tool.

Price Flexibilities of Bottomfish Species

As previously mentioned, price flexibilities are an important tool in understanding the demand structure and market interrelationships of various fish species in the marketplace. The price flexibility is the inverse demand analogue of traditional demand elasticities, as it measures the percentage change in price given a percentage change in quantities. These estimates allow researchers to assess the pricing implications of quantity-based management actions. The price effects of single-species management can be estimated through own-price flexibilities, while cross-price flexibilities shed light on the substitutability of fish species and detail potential ‘spillover’ effects from single-species management actions. In addition, the scale flexibility relates an individual species to the aggregate market, suggesting how changes in total market size affect individual species prices, all else held constant.

---

[10] For model-specific results (coefficients and model performance), see Section A4 in the Appendix.

Table 6.—Compensated price flexibilities, DGIDS model.

	Price Flexibilities (standard errors)						
	MHI Deep 7	NWHI Deep 7	Imports	Uku	Other BMUS	Reef fish	Scale (f_i)
MHI Deep 7	– 0.735*	0.043	0.234*	0.035	0.008	0.414*	– 2.502*
	(0.028)	(0.157)	(0.062)	(0.290)	(0.822)	(0.025)	(0.038)
NWHI Deep 7	0.079	– 0.731*	0.151*	0.025	0.017	0.458*	– 2.127*
	(0.089)	(0.030)	(0.064)	(0.290)	(0.822)	(0.030)	(0.058)
Imports	0.162	0.058	– 0.597*	0.065	0.016	0.296*	– 1.759*
	(0.087)	(0.157)	(0.024)	(0.290)	(0.822)	(0.021)	(0.036)
Uku	0.117	0.046	0.312*	– 0.896*	0.034	0.386*	– 1.901*
	(0.092)	(0.159)	(0.69)	(0.039)	(0.822)	(0.042)	(0.089)
Other BMUS	0.080	0.091	0.222*	0.098	– 0.941*	0.449*	– 1.972*
	(0.096)	(0.161)	(0.072)	(0.291)	(0.053)	(0.053)	(0.088)
Reef fish	0.239*	0.146	0.246*	0.067	0.027	– 0.725*	– 1.936*
	(0.087)	(0.157)	(0.061)	(0.290)	(0.822)	(0.025)	(0.027)

*Significant at the 5% level.

Compensated Own-Price Flexibility

All compensated own-price flexibility estimates (Table 6, diagonal) are negative and statistically significant. The negative sign of own-price flexibilities suggests that increases in own-quantities will translate to declines in own-prices. This is consistent with economic theory but is also closely related to the negativity condition of the Antonelli matrix, which follows from the fact that it must be negative semi-definite to address the quasi-concavity condition of the underlying utility function and thus satisfy demand theory (Barten and Bettendorf, 1989). It should be noted that these own-price flexibility estimates are all less than one in absolute terms, suggesting that these fish are price elastic; prices are not very responsive to quantity changes. A 1% decrease (increase) in quantities translates to a less-than-1% increase (decrease) in price. Other BMUS has the largest own-price flexibility (0.941 in absolute value), suggesting that prices for these species are more sensitive to a change in own quantities than the other fish species in our demand system. A 1% increase in the quantity of other BMUS is associated with a 0.941% decline in other BMUS price. Both MHI and NWHI Deep 7 prices are similarly responsive to own-quantity changes with flexibilities of – 0.735 and – 0.731, respectively. Fresh snapper and grouper imports exhibit the lowest price response relative to changes in own quantities at – 0.597. This implies that the prices of fresh snapper and grouper imports are more stable in response to own-quantity changes compared to locally caught bottomfish and reef fish. Thus, importers have reduced concern with regard to the level of imports they bring to market.

These results shed light on the tradeoffs managers face when implementing supply-side regulations. For example, a cut in MHI Deep 7 TAC level of 1%, all else held constant, will equate to a 0.735% increase in MHI Deep 7 prices. A clear implication of price elastic findings is that, in the context of TAC management, despite potential price increases in response to cuts in the future TAC levels (reduced quantities), total revenues may fall. This is based on the fact that the percentage change in quantity is greater than the subsequent percentage change in prices. This result is similar to findings in the literature (Eales et al., 1997; Park et al., 2004; Lee and Kennedy, 2008).

It is difficult to compare these flexibilities to those found in the literature, as the estimated flexibilities simply reflect the market conditions of the Hawaii bottomfish fishery and are limited to the definition of our demand system. Our estimates of flexibilities are larger than those found in an application to the Gulf of Mexico snapper and grouper management complex (Park et al., 2004), suggesting larger price effects from management actions in the Hawaii bottomfish fishery. However, our estimates are similar to those found in the Lee and Kennedy (2008) application to the U.S. crawfish industry.

Compensated Cross-Price Flexibility and Allais Coefficients

A negative cross-price effect implies that an increase in quantity of species *i* reduces the marginal valuation of species *j* which induces consumers to consume less of species *j*. In this situation, species *i* and species *j* are considered substitutes. Conversely, a positive cross-price effect implies that the increase in quantity of species *i* raises the marginal valuation of species *j* and induces consumers to consume more of species *j*, in which case, species *i* and species *j* would be recognized as complements.

While we find statistically significant cross-price flexibilities in every equation of the demand system, we find all cross-price flexibilities to be positive. This runs counter to the general notion that most fish are substitutable, but is potentially a result of an underlying bias built into the structure of our demand system construction. Our cross-price effects are biased towards complementarity as a result of our adding up restrictions. That is, each row of the Antonelli matrix (Table 6—not including the scale flexibility) must equal zero because of the homogeneity property of our system of budget share equations. As each fish species in our demand system is found to be a substitute of itself (negative own-price flexibility), the off-diagonal terms are skewed towards complementarity (positive sign) over substitutability (Park et al., 2004). This is common in the literature as nearly every study reports less cross-price substitutability than one would expect across species in their respective demand systems.

As Barten and Bettendorf (1989) suggest, and our results have validated, cross-price flexibilities are not the appropriate interaction measures among the various types of fish in exploring substitution effects because of the adding up condition in the Antonelli matrix, which causes cross-price flexibilities to be biased towards complementarity. Allais coefficients are an alternative measure and can be used to determine the intensity of substitution between fish species in our demand system. A number of studies have employed this approach to work around the inherent complementarity bias present in modern inverse demand systems (Barten and Bettendorf, 1989; Holt, 2002; Lee and Kennedy, 2008). Allais coefficients can be derived from each model's estimated Antonelli matrix and consumption scale flexibilities. These coefficients are calculated as follows:

$$\alpha_{ij} = a_{ij} / \sqrt{(a_{ii} a_{jj})^2} \tag{8}$$

$$\text{where} \quad a_{ij} = \pi_{ij} / w_i w_j - \pi_{rs} / w_r w_s + (\pi_i / w_i - \pi_r / w_r) + (\pi_j / w_j - \pi_s / w_s)$$

The computed Allais coefficients reflect the intensity of substitution between species *i* and *j* relative to a standard pair of goods, species *r* and *s*. To compute Allais interaction terms a standard pair of goods must be identified, and these terms range from – 1 to + 1. A value of – 1 would indicate perfect substitutes, thus, under this assumption we set the own-quantity Allais coefficients to negative one. A value of +1 would suggest perfect complements. An Allais coefficient less than zero indicates that species *i* and *j* are stronger substitutes than species *r* and *s*. On the other hand, an Allais coefficient value greater than zero would suggest that species *i* and *j* are more complementary than species *r* and *s*. By construction, the interaction term between the standard pair of goods is zero. We present an example of calculated Allais coefficients, validating substitutability between fish species in our demand system.

Table 7.—Estimated Allais coefficients, DGIDS model.

	MHI Deep 7	NWHI Deep 7	Imports	Uku	Other BMUS	Reef fish
MHI Deep 7	– 1.0000	– 0.6414	– 0.4442	– 0.2326	– 0.1351	– 0.1513
NWHI Deep 7		– 1.0000	– 0.9730	– 0.4704	– 0.1476	– 0.0738
Imports			– 1.0000	0.0176	– 0.1075	– 0.1864
Uku				– 1.0000	0.0413	– 0.0325
Other BMUS					– 1.0000	0.0000
Reef fish						– 1.0000

Base relationship: r = other BMUS, s = reef fish

The results in Table 7 indicate that all species in our demand system are more substitutable than the standard good pair (other BMUS and reef fish). MHI Deep 7 species, with an Allais coefficient value (α) of – 0.6414 with NWHI Deep 7, are strong substitutes with NWHI Deep 7, and moderate substitutes with fresh snapper and grouper imports ($\alpha = -0.4442$). Uku also substitute for MHI Deep 7 ($\alpha = -0.2326$), but the relationship is weaker in comparison to NWHI Deep 7 and fresh snapper and grouper imports. Additionally, NWHI Deep 7 species are found to be near perfect substitutes with fresh snapper and grouper imports, relative to the standard pair of goods, with $\alpha = -0.973$. This implies that the permanent closure of NWHI bottomfish fishery after 2011 may lead to further increases in fresh snapper and grouper imports to Hawaii to satisfy market demand, as they replace domestic NWHI bottomfish in the marketplace. While a few uku interaction values are greater than zero, suggesting complementarity, one could argue that in these cases intensity of substitution is negligible, relative to the standard pair of goods as uku has an interaction value of 0.0413 with other BMUS and a mere 0.0176 with fresh snapper and grouper imports.

These findings give credence to the potential for 'spillover' effects from supply-side fishery management actions within the Hawaii bottomfish fishery. When fishing is closed for MHI Deep 7, price pressures in the short term may increase fishing pressure on the NWHI Deep 7, uku, reef fish, and other BMUS stocks. Because almost all MHI fishers do not have access to the limited-entry NWHI fishery zone, we may see shifts in effort to MHI uku, reef fish, and other BMUS. Likewise, pressure could increase outside of this demand system to pelagic species. The current management regime focused on MHI Deep 7 species may have unintended pricing consequences on other fish, shown here to be related in the marketplace.

Scale Flexibility

To consider the relationship between aggregate market size and individual species (group) prices we calculated scale flexibilities. All scale flexibilities are negative and statistically significant, which makes sense, as one would expect that as aggregate market fish quantity increases, individual species' normalized prices might decline. A scale flexibility of – 1 indicates homothetic preferences, meaning that the relative price and sales share are constant, given a change in quantity. Our estimated scale flexibilities are significantly different from – 1 suggesting that the underlying scale curves differ significantly from both linear and linear logarithmic forms, as found in Lee and Kennedy (2008). In considering the relative magnitudes of species' scale flexibilities in our demand system, our findings suggest that fresh snapper and grouper import prices ($f_i = -1.759$) are the least responsive to changes in aggregate market size, while MHI Deep 7 species ($f_i = -2.502$) are the most responsive to changes in aggregate market size. This means a 1% increase in aggregate market supply, all else held constant, will decrease the marginal valuation of MHI Deep 7 prices by approximately 2.5%. This has important considerations for TAC management as any potential reductions in MHI Deep 7 TAC levels may not trigger the expected price increase for domestic fishers if aggregate market size increases as a result of increased landings in other domestic substitutes or influxes in fresh snapper and grouper imports. This creates difficulty in balancing conservation efforts with economic considerations.

Uncompensated Price Flexibility

The uncompensated price flexibilities capture the effects of scale and substitution effects as one. Our estimated uncompensated price flexibilities (Table 8) affirm that all fish species in our demand system are substitutes. However, it is clear that scale effects are present and the magnitude dominates the substitution effect in the Hawaii bottomfish market (Table 6). Based on our estimated compensated price flexibilities and scale flexibilities, it would appear changes in aggregate market supply have a greater effect on prices rather than individual quantity changes, all else held constant. Thus, any expected price effects from changes in domestic Deep 7 TAC levels may be buffered by aggregate market size fluctuations brought on by influxes of fresh snapper and grouper imports and/or nonmanaged domestic species. The presence of scale effects also suggests that uncompensated flexibilities may overestimate the quantity effect on prices (Lee, 2007).

Table 8.—Uncompensated price flexibilities, DGIDS model.

	Price Flexibilities					
	MHI Deep 7 (1)	NWHI Deep 7 (2)	Imports (3)	Uku (4)	Other BMUS (5)	Reef fish (6)
1	– 1.223	– 0.225	– 0.470	– 0.111	– 0.043	– 0.431
2	– 0.335	– 0.960	– 0.447	– 0.099	– 0.026	– 0.260
3	– 0.180	– 0.131	– 1.091	– 0.038	– 0.020	– 0.298
4	– 0.253	– 0.158	– 0.222	– 1.007	– 0.005	– 0.256
5	– 0.304	– 0.120	– 0.333	– 0.017	– 0.981	– 0.217
6	– 0.138	– 0.062	– 0.298	– 0.046	– 0.012	– 1.379

Welfare Effects of MHI Deep 7 TAC Management

When fishery regulations change market quantities, consumers and downstream firms may be made better off or worse off depending on price and scale flexibilities. As we have established the presence of sizable scale effects associated with changes in MHI Deep 7 quantities, consumer's surplus is not the appropriate measure for assessing welfare changes as a result of fishery management actions. In light of scale effects, we calculate exact welfare changes using the compensating variation measure. For an increase in quantities, consumers and downstream firms are better off based on decreased prices. Likewise, for a decrease in quantities, consumers will face higher prices and thus are worse off. The estimated welfare effects associated with changes in MHI Deep 7 TAC levels are presented in Table 9 with the 2009 TAC level of 241,000 pounds serving as the base measure.

Table 9.—Estimated welfare effects (2008 dollars) associated with changes in MHI Deep 7 TAC levels.

		DGIDS model			
		Compensating		95% Confidence Limits	
TAC level (1,000 pounds)	% change	Variation (dollars)	Standard error	Lower	Upper
121	– 50	– 943,607	1,705	– 947,260	– 939,954
145	– 40	– 731,625	1,391	– 734,606	– 728,645
169	– 30	– 531,274	1,604	– 533,553	– 528,995
193	– 20	– 342,553	723	– 344,101	– 341,004
217	– 10	– 165,462	368	– 166,250	– 164,672
241	0	No Change	-	-	-
265	+ 10	153,831	382	153,013	154,650
289	+ 20	296,032	777	294,367	297,698
313	+ 30	426,603	1,186	424,062	429,146
337	+ 40	545,545	1,609	542,097	548,993
362	+ 50	652,856	2,046	648,473	657,238

Our calculated welfare measures allow fishery managers implementing TAC regulations to balance economic considerations with conservation concerns by presenting the estimated changes in welfare to consumers and downstream firms associated with TAC management decisions. It is clear from Table 9 that a tradeoff exists between short-term costs of management (for example, a 50% reduction in MHI Deep 7 TAC levels will result in an approximate $0.9 million in welfare loss) and long-term economic and biological gains from conservation, as evident by the fact that increases in TAC levels will make consumers and downstream firms better off. These welfare changes are far lower than those estimated in Park et al. (2004) but reflect the smaller scale of the Hawaii bottomfish fishery relative to the Gulf of Mexico snapper and grouper fishery, where average monthly landings exceed the annual levels for our entire demand system.

Other information is needed to provide a complete analysis of economic impacts. For example, we do not have estimates of producer (fisher) welfare associated with changes in MHI Deep 7 TAC levels. Given a valid cost function, the cost flexibilities could determine how a change in quantities would affect trip costs and, subsequently, net revenues. Estimates of producer surplus, coupled with our estimated compensating variation measures, would provide estimates of net social welfare changes in response to MHI Deep 7 TAC changes. This holistic measure would more accurately portray the true economic costs of TAC management in the Hawaii bottomfish fishery. In addition, the social value of bottomfish and bottomfish fishing should be considered alongside these market-based estimates of value.

Seasonality and Macroeconomic Conditions

The seasonality of the Hawaii bottomfish fishery has become increasingly relevant in light of the emergency seasonal closure enacted in 2007 and the closures that go into effect if and when an annual TAC is reached. One could use the seasonal dummies from our demand estimations to explore seasonal demand swings within our demand system. Care should be taken in direct interpretation of the dummy variables because our dependent variable is species *i* budget expenditure share, not directly price or quantity. With that in mind, however, the month of December shows the highest budget expenditure share for MHI and NWHI Deep 7 species as evidenced by statistically significantly negative values for seasonal dummies (see appendix – Table A7). The negative sign indicates that the budget expenditure share for each month is less than for the base case of December. This validates the market importance for domestic Deep 7 fish during the December holiday season. In fact, all domestic bottomfish models follow this result. However, seasonal dummies for fresh snapper and grouper imports and domestic reef fish are all positive, suggesting reduced demand for these species groups during December. Aside from December, if we consider the relative magnitudes of seasonal price effects for MHI Deep 7 we find that the budget expenditure shares are highest in February, May, and November, corresponding to Chinese New Year, graduation season, and Thanksgiving, respectively. Therefore, it is clear that demand for MHI Deep 7 bottomfish varies seasonally based on cultural considerations, and managers should incorporate this finding into any future seasonal regulatory measures.

In addition to seasonality, macroeconomic conditions inherently play a role in bottomfish price formation. The current structure of this analysis does not consider tourism, which is an important external factor. The economy of the State of Hawaii is heavily reliant on tourism and as mentioned in the introduction, a portion of the Hawaii bottomfish market serves the upscale restaurant sector which is reliant, in part, on tourists. Tourism appears to be a significant factor in bottomfish price formation[11], and tourist levels should be taken into consideration when assessing bottomfish pricing trends in the future.

CONCLUSIONS

Using recent methodological advances, this paper analyzes demand relationships for the Hawaii bottomfish fishery, enabling fishery managers to consider economics in bottomfish TAC management decisions. The research introduces a generalized inverse demand system, as applied to the Hawaii bottomfish fishery, and details market linkages between various fish species in the Hawaii bottomfish market. We found negative and statistically significant own-quantity price flexibilities indicating that Hawaii bottomfish prices increase as own-supply declines. However, the demand estimates also show that Hawaii bottomfish prices are rather price elastic and, therefore, not very responsive to own-quantity changes. Declines in MHI Deep 7 TAC levels will translate, all else held constant, to increased MHI Deep 7 prices. However, these increases in prices may still translate to declines in total revenues, as the percentage change in quantities is greater than the percentage change in prices. Additionally, increases in TAC levels will decrease prices, whereby fishery revenues may actually decline, especially if aggregate market supply increases to fill demand or available market supply are poorly timed. This complicates the ability of fishery managers to balance conservation and economic considerations.

We found that scale effects dominate substitution effects for our defined demand system. This indicates that the aggregate market supply plays a large role in price determination for the Hawaii bottomfish

---

[11] To explore the role of tourism on bottomfish price formation, a SUR estimation of a log-linear system of inverse demand equations of the form: $\ln p_i = \alpha + \ln q_i + \ln q_{-i} + \sum_{k=1}^{11} \delta D_k + \ln Q_{visitors} + \varepsilon$ was performed using the same data set. The number of visitors to the State of Hawaii was found to be statistically significant (at the 95% level) and positive in all domestic bottomfish models (MHI Deep 7, NWHI Deep 7, uku, other BMUS). It was not found to be statistically significant for fresh snapper and grouper imports or domestic reef fish.

fishery. We find all species in our demand system to be substitutes in the marketplace implying that MHI Deep 7 TAC decisions may have economic ‘spillover’ effects. For example, any potential reductions in TAC levels for MHI Deep 7 species may translate to increased demand for other domestic species. This could have the unintended consequence of increased prices for nonregulated species and may lead to increased fishing pressure. Accordingly, biological indicators for nonregulated and substitute species must be closely monitored. It is also clear that demand for MHI Deep 7 bottomfish varies seasonally due to cultural considerations, and managers should incorporate this finding into any future seasonal regulatory measures. Specifically, December is the month of peak demand and a lack of domestic Deep 7 bottomfish during this month will have profound economic and cultural implications. Short-run macroeconomic considerations, such as tourism, also play a role in bottomfish demand and price formation.

This research should be considered in the context of several limitations. For one, we have confined our demand system to a small percentage of the Hawaii seafood market, thus we may be leaving out important inter-market linkages. This could be pursued in future research by incorporating the pelagic market and other seafood products prevalent in Hawaii (salmon, shellfish, freshwater species, amongst others). Additionally, this methodology is not currently structured to account for the dynamic complexities of a globalized marketplace and thus can only present an analysis of independent marginal changes within the fishery. Lastly, the social and cultural importance of MHI Deep 7 bottomfish was not quantified here, but should be considered along with biological and economic factors in managing the fishery.

REFERENCES

Anderson, Ronald W.
1980. Some Theory of Inverse Demand for Applied Demand Analysis. European Economic Review. 14(3): 281–90.

Barten, A. P., and L. J. Bettendorf.
1989. Price Formation of Fish: An Application of an Inverse Demand System. European Economic Review. 33(8): 1509–25.

Brodziak, Jon, Robert Moffitt, and Gerard DiNardo.
2009. Hawaii Bottomfish Assessment Update for 2008. Pacific Islands Fisheries Science Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96822–2396. Pacific Islands Fisheries Science Center Administrative Report H-09-02. 93 p.

Brown, Mark G., Jonq–Ying Lee, and James L. Seale Jr.
1995. A Family of Inverse Demand Systems and Choice of Functional Form. Empirical Economics. 20(3): 519–30.

Eales, J., C. Durham, and C.R. Wessells.
1997. Generalized Models of Japanese Demand for Fish. American Journal of Agricultural Economics. 79: 1153–63.

Freeman, A. Myrick III.
2003. The Measurement of Environmental and Resource Values: Theory and Methods. Second edition. RFF Press, Washington, DC.

Grafton, R. Queton, Linwood H. Pendleton, and Harry W. Nelson.
2001. A Dictionary of Environmental Economics, Science, and Policy. Edward Elgar Publishing, Inc. Massachusetts, USA.

Greene, William H.
2003. Econometric Analysis. Fifth Edition. Pearson Education, India.

Hausman, J.A.
1978. Specification Tests in Econometrics. Econometrica. 46: 1251–71.

Hilmer, Christiana E., Matthew T. Holt, and Richard C. Bishop.
2004. Bootstrapping Your Fish Or Fishing for Bootstraps? Precision of Welfare Loss Estimates from a Globally Concave Inverse Demand Model of Commercial Fish Landings in the U.S. Great Lakes. Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Denver, Colorado, August 1–4, 2004 ed., June 28, 2004.

Holt, Matthew T.
2002. Inverse Demand Systems and Choice of Functional Form. European Economic Review 46: 117–42.

Holt, Matthew T., and Richard C. Bishop.
2003. Measuring Interrelated Demands for Commercially Caught Fish. Unpubl. manuscr. (University of Wisconsin–Madison)

Holt, Matthew T., and Richard C. Bishop.
2002. A Semiflexible Normalized Quadratic Inverse Demand System: An Application to the Price Formation of Fish. Empirical Economics 27(1): 23–47.

Laitinen, K. and H. Theil.
1979. The Antonelli Matrix and the Reciprocal Slutsky Matrix. Economics Letters 3: 153–57.

Lee, Youngjae.
2007. Analysis of the Impact of Fish Imports on Domestic Crawfish Prices and Economic Welfare Using Inverse Demand Systems. Doctoral Thesis. Louisiana State University and Agricultural and Mechanical College.

Lee, Youngjae and P. Lynn Kennedy.
2008. An Examination of Inverse Demand Models: An Application to the US Crawfish Industry. Agricultural and Resource Economics Review 37(2): 243–56.

Maynard, Leigh J. and Venkat N. Veeramani.
2003. Price Sensitivities for U.S. Frozen Dairy Products. Journal of Agricultural and Applied Economics. 35(3): 599–609.

Moffitt, Robert B., Donald R. Kobayashi, and Gerard T. DiNardo.
2006. Status of Hawaiian Bottomfish Stocks, 2004. Pacific Islands Fisheries Science Center, National Marine Fisheries Service, NOAA, Honolulu, HI 96822–2396. Pacific Islands Fisheries Science Center Administrative Report H-06-01. 45 p.

Neves, P.D.
1994. A Class of Differential Demand Systems. Economic Letters. 44: 83–7.

NOAA, Office of Inspector General.
1992. North Pacific Fisheries Amendments Lack Adequate Support. NOAA-4437-2-0001. Washington DC.

Park, Hoanjae, Walter N. Thurman, and J. E. Easley.
2004. Modeling Inverse Demands for Fish: Empirical Welfare Measurement in Gulf and South Atlantic Fisheries. Marine Resource Economics. 19(3): 333–51.

Pooley, Samuel G.
1987. Demand Considerations in Fisheries Management – Hawaii's Market for Bottom fish. *In* Polovina JJ, Ralston S (eds.) Tropical snappers and groupers: biology and fisheries management, 605–38. Westview Press, Boulder, CO.

Thurman, Walter N.
1986. Endogeneity Testing in a Supply and Demand Framework. Review of Economics and Statistics 68(4): 638–46.

Wagner, John E., Valerie A. Luzadis, and Donald W. Floyd.
1998. A Role of Economic Analysis in the Ecosystem Management Debate. Lands. Urban Plann. 40: 151–57

Willig, Robert D.
1976. Consumer's Surplus without Apology. American Economic Review 66(4): 589–97.

APPENDIX

A1. BOTTOMFISH MANAGEMENT UNIT SPECIES (BMUS) NAMES

Table A1.—List of bottomfish management unit species (BMUS).

Scientific name	English common name	Hawaii name
Aphareus rutilans	red snapper/silvermouth	lehi
Aprion virescens	gray snapper/jobfish	uku
Caranx ignobilis	giant trevally/jack	white ulua/pau’u
C. lugubris	black trevally/jack	black ulua
Epinephelus quernus	sea bass	hapu'upu’u
Etelis carbunculus	red snapper	ehu
E. coruscans	red snapper	onaga
Lutjanus kasmira	blueline snapper	ta’ape
Pristipomoides auricilla	yellowtail snapper	yellowtail kalekale
P. filamentosus	pink snapper	‘ōpakapaka
P. flavipinnis	yelloweye snapper	yelloweye opakapaka
P. seiboldi	pink snapper	kalekale
P. zonatus	snapper	gindai
Pseudocaranx dentex	thicklip trevally	butaguchi/pig ulua
Seriola dumerili	amberjack	kahala

A2. THEORETICAL FRAMEWORK

This section follows the theoretical presentation found in Park et al. (2004) and presents the underlying theoretical framework for the demand analysis presented in this paper. The theoretical foundation for this research is well established (Anderson, 1980; Laitinen and Theil, 1979; Barten and Bettendorf, 1989; Neves, 1994; Brown et al., 1995). Due to the perishable nature of fish, we begin by specifying an inverse demand system

$$p_i = g_i(q_1, \ldots, q_n, m),\ i = 1, \ldots, n \qquad \text{(A1)}$$

where p_i and q_i are the respective prices and quantities for the *i*th fish type and *m* is total expenditure for *n* goods. Using the fact that the g_i are linearly homogenous in *m*, this can be written in normalized form:

$$v_i = g_i(q_1, \ldots, q_n),\ i = 1, \ldots, n \qquad \text{(A2)}$$

where v_i is the normalized price of fish type *i*: $v_i = p_i/m$. Following Park et al. (2004), the utility theoretic restrictions on demand functions, assuming differentiability, can be expressed conveniently in terms of the derivatives of the normalized functions. The log differentials of the inverse demands are:

$$d \ln v_i = \sum_j b_{ij} d \ln q_j \qquad \text{(A3)}$$

where b_{ij} are the uncompensated price flexibilities (elasticities of price with respect to quantities) of fish type *i* (Park et al., 2004). From here, one can derive the scale and substitution effects in response to quantity changes and through substitution arrive at the empirical form of the Inverse Rotterdam Demand System (IROT):

$$w_i d\ln v_i = \sum_j h_{ij} d\ln q_j + h_i d\ln Q \qquad \text{(A4)}$$

where w_i is budget share ($w_i = v_i q_i$) and $d\ln Q$ is a differential Divisia quantity index. In addition, alternative inverse differential demand systems have been developed in the literature. Barten and Bettendorf (1989) derived a linear version of the inverse Almost Ideal Demand System (IAIDS) as:

$$dw_i = \sum_j c_{ij} \Delta\ln q_j + c_i \Delta\ln Q \qquad \text{(A5)}$$

The inverse CBS model (ICBS) was initially proposed by Laitinen and Theil (1979) and further presented in Barten and Bettendorf (1989). The ICBS system is derived by adding $w_i d\ln Q$ to both sides of the IROT specification, which simplifies to:

$$w_i d\ln\left(\frac{p_i}{p}\right) = \sum_j h_{ij} d\ln q_j + c_i d\ln Q \qquad \text{(A6)}$$

where $d\ln P = \sum_j w_j d\ln p_j$ is the log change in the Divisia price index. The relative price of commodity *i*, p_i, is the dependent variable in the ICBS model and is related to the previous models in that it shares scale coefficients with the IAIDS model and quantity coefficients with the IROT specification (Park et al., 2004). However, when one subtracts $w_i d\ln Q$ from both sides of the IAIDS, one can arrive at the inverse NBR system (INBR) as proposed by Neves (1994).

$$dw_i - w_i d\ln Q = \sum_j c_{ij} d\ln q_j + h_i d\ln Q \qquad \text{(A7)}$$

Subsequently, this specification shares scale coefficients with the IROT model and IAIDS quantity coefficients. Brown et al. (1995) were able to recognize that these demand specifications were intrinsically linked. By exploiting this fact, were able to nest these four inverse demand systems into a generalized inverse demand system (GIDS) specification as follows:

$$w_i d\ln p_i = \sum_{j=1} \pi_{ij} d\ln q_j + \pi_i d\ln Q \; - \theta_1 w_i d\ln Q \; - \theta_2 w_i d\ln(q_i / Q\,) \qquad \text{(A8)}$$

The strong seasonality aspects of the bottomfish fishery prompts us to include monthly dummies, $\sum_{k=1}^{11} \delta D_{kt}$ with December as the base. Additionally, following Lee and Kennedy (2008) this study modifies the specification to reflect the discrete-time nature of the data and the $\overline{w}_{it}$ term, the 2 year moving average in the budget expenditure share of good i, is used in this study to avoid a simultaneity problem. Our final empirical Differential Generalized Inverse Demand System (DGIDS) specification is as follows:

$$\bar{w}_{it}\Delta \ln p_{it} = \alpha_i + \sum_{k=1}^{11} \delta D_{kt} + \sum_{j=1}^{6} \pi_{ij} \Delta \ln q_{jt} + \pi_i \Delta \ln Q_t - \theta_1 \bar{w}_{it} \Delta \ln Q_t - \theta_2 \bar{w}_{it} \Delta \ln(q_{it} / Q_t) + \varepsilon_{it} \tag{A9}$$

$$where \;\; \Delta \ln Q_t = \sum_{j=1}^{6} \bar{w}_{jt} \ln q_{jt} \;,\;\; \bar{w}_{it} = \frac{w_{it} + w_{it-1}}{2}, \text{ and } \Delta \ln p_{it} = \ln p_{it} - \ln p_{it-1}$$

Parametric restrictions can be imposed to our empirical model specification to ensure that our inverse demand system adheres to microeconomic theory, specifically, theoretical requirements of demand curves such as adding up, homogeneity, and symmetry.

(1) $\sum_i (\pi_{ij} - \theta_1 w_i) = -1$
(2) $\sum_i (\pi_{ij} - \theta_2 w_i \delta_{ij} + \theta_2 w_i w_j) = \sum_i \pi_{ij} = 0$
(3) $\sum_j (\pi_{ij} - \theta_2 w_i \delta_{ij} + \theta_2 w_i w_j) = \sum_j \pi_{ij} = 0$
(4) $\pi_{ij} = \pi_{ji}$
(5) $\sum_i \alpha_i = 0$
(6) $\sum_i \delta_{ik} = 0$ for $k = 1, \ldots, 11$

Restrictions (1), (2), (5) and (6) satisfy adding up requirements. Homogeneity is met through restriction (3), while symmetry is ensured through restriction (4). Adding up implies singularity of the error variance-covariance matrix and can be imposed by dropping one of the equations in the estimation (Park et al., 2004). Homogeneity ensures that a proportionate increase in quantity is neutralized as far as the substitution effect is concerned (Barten and Bettendorf, 1989). Symmetry ensures that estimated cross-effects are equal across models.

The empirical estimation of price flexibilities (percentage change in price in response to a percentage change in quantities) varies across model specifications, and a summary is presented below in Table A2.

Table A2.—Compensated and uncompensated price flexibility calculation by model specification.

	GIDS (eq. A8)	**IROT** (eq. A4)	**IAIDS** (eq. A5)	**ICBS** (eq. A6)	**INBR** (eq. A7)
f_{ij}^{*}	$\frac{\pi_{ij}}{w_i} + \theta_2 w_j$	$\frac{h_{ij}}{w_i}$	$\frac{c_{ij}}{w_i} + w_j$	$\frac{h_{ij}}{w_i}$	$\frac{c_{ij}}{w_i} + w_j$
f_{ij}	$\frac{\pi_{ii} - \pi_i w_j}{w_i} + (\theta_2 - \theta_1) w_j$	$\frac{h_{ij} - h_i w_j}{w_i}$	$\frac{c_{ij} - c_i w_j}{w_i}$	$\frac{h_{ij} - (c_i + w_i) w_j}{w_i}$	$-h_i \frac{w_j}{w_i} + \frac{c_{ij}}{w_i} + w_j$

f_{ij}^{*} : Compensated cross price flexibility

f_{ij} : Uncompensated cross price flexibility

(adapted from Lee, 2007)

Welfare

The classical economic measure of welfare change is consumer's surplus (CS). CS refers to the difference between the maximum that a consumer is prepared to pay and the amount the consumer actually pays (Grafton et al., 2001). However, CS can be an exact measure of welfare change only in special circumstances (Willig, 1976). CS is relevant when preferences are homothetic or when a quantity change has no scale effects. Homothetic preferences are, however, unrealistic, and commodity demands are found to have pronounced scale effects (Lee, 2007). The uncompensated price flexibilities allow us to estimate consumer surplus. As uncompensated flexibility overestimates the quantity effect on price, in cases where the quantity effect includes both substitution and scale effects, the CS is only an approximate measure (Willig, 1976, Lee, 2007). However, compensated flexibilities exactly measure welfares changes in which the scale effect can be separated from the substitution effect in response to a quantity change.

Compensating Variation

The compensating variation (CV) measure asks what compensating payment (that is, an offsetting change in income) is necessary to make the individual indifferent between the original situation and the new price set (Freeman, 2003). This can be measured by the area under the compensated inverse demand curve between the original quantity level (q^0) and the new quantity level (q^1) with the old and new utility levels, respectively. For an increase in the quantity of one good *j*, the compensated demand curve lies below the uncompensated demand curve because of the negative scale effect when the good in question is a normal good. Compensating Variation is shown below in Figure A1:

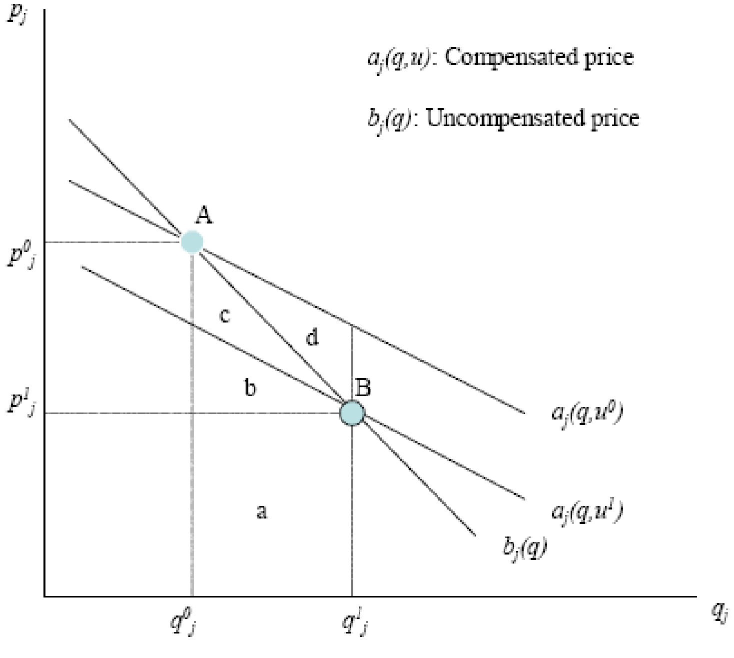

Figure A1.—The welfare effects of a quantity change (Lee, 2007).

The compensating variation for a quantity increase is the area (a + b + c + d). For the case of increased quantities this measure is positive as consumers and downstream firms are made better off through decreased prices.

A3. MODEL SPECIFICATION

Our empirical generalized inverse demand system involves budget share equations to explore demand relationships for fish species interrelated in the marketplace. Zellner's Seemingly Unrelated Regression (SUR) was used as an econometric estimation methodology because it was sensible to assume that individual fish products are contemporaneously correlated in consumption as substitutes (Greene, 2003). In estimation, to impose the adding-up restriction of the errors, we dropped the 'other BMUS' model. Based on symmetry conditions, we can easily recover the parameters from the estimated models. A priori theory does not provide guidance on the appropriate functional form for demand analyses. A feature of the DGIDS is that it nests four popular demand models (IAIDS, IROT, ICBS, INBR) using a pair of mixing parameters. Based on the estimated mixing parameters, the DGIDS may reduce to one of the four nested submodels. By empirically estimating the mixing parameters, we allow the data to determine the appropriate functional form for our analysis.

Table A3.—Estimated mixing parameters from DGIDS model.

Mixing Parameter	Standard Error
$\theta_1 = 1.01537$	0.0079
$\theta_2 = 0.89658$	0.0176

We obtained mixing parameters very close to the (1,1) configuration, which would suggest that the IAIDS model may be the appropriate submodel for our demand analysis (Table A3). However, we conducted statistical tests to determine the validity of these estimated parameters. Wald likelihood ratio tests were performed on the mixing parameters to determine if they were statistically different from zero or one (see Table A4). It is clear that we fail to reject the null hypothesis of $\theta_1 = 0$, so this parameter is in fact not statistically different than zero.

Table A4.—Test statistics for nested model restrictions.

Null hypothesis	F (p-value)
$\theta_1 = 0$	1.19 (0.2765)
$\theta_1 = 1$	5178 (0.0001)
$\theta_2 = 0$	11.03 (0.0009)
$\theta_2 = 1$	829 (0.0001)
DIROT $(\theta_1 = 0,\ \theta_2 = 0)$	2665 (0.0001)
DIAIDS $(\theta_1 = 1,\ \theta_2 = 1)$	7.35 (0.0007)
DICBS $(\theta_1 = 1,\ \theta_2 = 0)$	2803 (0.0001)
DINBR $(\theta_1 = 0,\ \theta_2 = 1)$	431 (0.0001)

Additionally, we reject the null hypothesis that $\theta_1 = 1$, meaning that the mixing parameter is statistically different from one. Likewise, the second mixing parameter provides similarly problematic results as we reject the null of $\theta_2 = 0$ and $\theta_2 = 1$. This finding is common in the literature (Brown et al., 1995; Eales et al., 1997; Park et al., 2004; Lee, 2007).

These results suggest that none of the submodels is appropriate for our data set and support our use of the generalized model. In addition, joint likelihood ratio tests were applied to test the validity of the submodels, and based on the results in Table 7, we again reject all submodels. The DGIDS is the best fit for our data, and we proceed with strictly presenting estimates from this model specification.

Autocorrelation

The presence of serial correlation in time series data is common. This study tested for the degree of serial correlation using a system-wide Breusch Godfrey test:

$$\varepsilon_{it} = \rho_1 \varepsilon_{it-1} + \rho_2 \varepsilon_{it-2} + u_{it}, \quad i = 1,\ldots,6 \qquad \text{(A10)}$$

Evidence of second-order autocorrelation was found and FGLS procedures were employed to correct for this condition. The estimated autocorrelation parameters are shown in Table A5. To preserve the adding- up condition for our demand system, the autocorrelation coefficients are constrained to be the same in all equations.

Table A5.—Estimated autocorrelation parameters.

Autocorrelation Parameter	Standard Error	t-Value	p-value
$\rho_1 = -0.4347$	0.0842	-5.16	< 0.0001
$\rho_2 = -0.3112$	0.0839	-3.71	0.0003

The estimated autocorrelation parameters are used to transform the model according to the autoregressive FGLS formula:

$$\begin{aligned} x_1^* &= \left[\frac{(1+\rho_2)[(1-\rho_2)^2 - \rho_1^2]}{(1-\rho_2)} \right]^{\frac{1}{2}} x_1 \\ x_2^* &= (1-\rho_2^2)^{\frac{1}{2}} x_2 - \left[\frac{\rho_1 (1-\rho_1^2)^{\frac{1}{2}}}{(1-\rho_2)} \right] x_1 \qquad \text{(A11)} \\ x_t^* &= x_t - \rho_1 x_{t-1} - \rho_2 x_{t-2} \qquad \text{for } t > 2 \end{aligned}$$

Table A6.—Estimated autocorrelation parameters (post-correction).

Autocorrelation Parameter	Standard Error	t-Value	p-value
$\rho_1 = -0.0611$	0.0877	-5.16	0.4873
$\rho_2 = 0.1156$	0.0878	1.32	0.1901

The post-correction test statistics (Table A6) validate that this transformation corrected for the second-order autocorrelation.

Endogeneity

A primary requirement for a valid inverse demand system is that the price is endogenous and quantity is exogenous (Anderson, 1980; Barten and Bettendorf, 1989; Brown et al., 1995). In framing the empirical specification, once the model has been identified and serial correlation accounted for it is important to explore for potential endogeneity in the explanatory variables. An endogenous variable is one whose value is determined within the framework of an econometric model, while an exogenous variable is anything predetermined or fixed in the economic analysis. The value of an exogenous explanatory variable is not determined within an economic model, but it plays a role in determination of the values of endogenous variables.

In a quota management regime, it is clear that quantities could be treated as exogenous because fishers are limited to a specific fixed total allowable catch for a fishing season. However, for the timeframe of our data set, none of the species in this analysis were managed with a quota system, thus one would not necessarily presume that quantities would be treated as exogenous. One could argue that fishers behave strategically and base their effort on market conditions and expected ex-vessel price, which would suggest endogeneity in quantities. Rather than imposing these assumptions based on anecdotal evidence, one can employ formal tests to validate this conjecture and ensure the validity of our inverse demand system. While there are numerous tests for varying degrees of exogeneity, the data were tested for exogeneity in price and quantity using the straightforward Wu-Hausman test (Hausman, 1978; Thurman, 1986; Maynard and Veeramani, 2003).

The systemwide analog to the Wu-Hausman test was performed by regressing potentially endogenous variables on a set of exogenous and predetermined instruments (lagged values) and including the residuals as regressors in the original demand specification (Maynard and Veeramani, 2003). The quantity terms ($\Delta \ln q_i$) were jointly tested and we failed to reject the null hypothesis of exogeneity with an *F*-statistic of 0.85, well below the critical value $F_{.05}(6,110)$ of 2.18. Likewise, in testing for exogeneity in prices we reject the null hypothesis of exogeneity with an *F*-statistic of 15.74, far exceeding the critical value. Therefore, we conclude with confidence that our quantities can be treated as exogenous and prices as endogenous, meeting the requirements of a valid inverse demand system. Additionally, we can be assured that our inverse demand system can be consistently estimated using the SUR estimation technique.

A4. ESTIMATED COEFFICIENTS

We estimated our system of inverse demand share equations using Seemingly Unrelated Regression (SUR) estimation. Estimation results are presented in Table A7. We preface the results by presenting the empirical econometric model for review:

$$\bar{w}_{it}\Delta \ln p_{it} = \alpha_i + \sum_{k=1}^{11}\delta D_{kt} + \sum_{j=1}^{6}\pi_{ij}\Delta \ln q_{jt} + \pi_i \Delta \ln Q_t - \theta_1 \bar{w}_{it}\Delta \ln Q_t - \theta_2 \bar{w}_{it}\Delta \ln(q_{it} / Q_t) + \varepsilon_{it}$$

$$where \ \ \Delta \ln Q_t = \sum_{j=1}^{6}\bar{w}_{jt}\ln q_{jt} \ , \ \bar{w}_{it} = \frac{w_{it} + w_{it-1}}{2}, \text{ and } \Delta \ln p_{it} = \ln p_{it} - \ln p_{it-1}$$

Table A7.—Estimated coefficients from SUR estimation: DGIDS model.

Model ($i = \ldots$)						
	MHI Deep 7	NWHI Deep 7	Imports	Uku	Other BMUS	Reef
intercept	0.01628*	0.00502*	– 0.00803*	0.00209	0.00161*	– 0.01697*
holiday1	– 0.01895*	– 0.00568*	0.01695*	– 0.00194	– 0.00201*	0.01163*
holiday2	– 0.01089*	– 0.00244	0.00683*	– 0.00173	– 0.00089	0.00911*
holiday3	– 0.02668*	– 0.00604*	0.01321*	– 0.00166	– 0.00310*	0.02427*
holiday4	– 0.01777*	– 0.01016*	0.00758*	– 0.00398**	– 0.00364*	0.02796*
holiday5	– 0.01277*	– 0.00669*	0.00474	– 0.00158	– 0.00306*	0.01937*
holiday6	– 0.02095*	– 0.00584*	0.01439*	– 0.00544*	– 0.00278*	0.02062*
holiday7	– 0.01982*	– 0.00682*	0.00694*	– 0.00222	– 0.00147*	0.02339*
holiday8	– 0.01970*	– 0.00267	0.00666**	– 0.00147	– 0.00151*	0.01869*
holiday9	– 0.02236*	– 0.00308	0.00655**	– 0.00066	– 0.00126**	0.02081*
holiday10	– 0.01460*	– 0.00247	0.00535	– 0.00063	– 0.00085	0.01319*
holiday11	– 0.01395*	– 0.00642*	0.00757*	– 0.00247	– 0.00098	0.01624*
$\Delta \ln q_{MD7}$	– 0.00214					
$\Delta \ln q_{PD7}$	– 0.00853*	0.00616*	Symmetry imposed			
$\Delta \ln q_{IMP}$	– 0.00291	– 0.00895*	0.01111*			
$\Delta \ln q_{UKU}$	– 0.00278**	– 0.00243**	0.00291**	– 0.00249		
$\Delta \ln q_{OTH}$	– 0.00161*	– 0.00008	– 0.00051	0.00077	– 0.00106	
$\Delta \ln q_{REEF}$	0.01797*	0.01383*	– 0.00164	0.00402*	0.002483*	– 0.03665*
$\Delta \ln Q$	– 0.28975*	– 0.11939*	– 0.2089*	– 0.05153*	– 0.01961*	– 0.31081*
θ_1	1.01537*	Assumed equal across all models				
θ_2	0.89658*					
adjusted R^2	0.9796	0.8789	0.9357	0.8827	0.7905	0.9325
Durbin-Watson	2.211	2.209	2.493	2.138	1.463	2.139

* Statistically significant at the 95% level.

**Statistically significant at the 90% level.

Availability of NOAA Technical Memorandum NMFS

Copies of this and other documents in the NOAA Technical Memorandum NMFS series issued by the Pacific Islands Fisheries Science Center are available online at the PIFSC Web site http://www.pifsc.noaa.gov in PDF format. In addition, this series and a wide range of other NOAA documents are available in various formats from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, U.S.A. [Tel: (703)-605-6000]; URL: http://www.ntis.gov. A fee may be charged.

Recent issues of NOAA Technical Memorandum NMFS–PIFSC are listed below:

NOAA-TM-NMFS-PIFSC-14 Hawaiian Archipelago Marine Ecosystem Research (HAMER).
HAWAII DIVISION OF AQUATIC RESOURCES, PAPAHĀNAUMOKUĀKEA MARINE NATIONAL MONUMENT, NOAA PACIFIC ISLANDS FISHERIES SCIENCE CENTER, UNIVERSITY OF HAWAII, U.S. FISH AND WILDLIFE SERVICE, WESTERN PACIFIC REGIONAL FISHERY MANAGEMENT COUNCIL (compilers)
(February 2008)

15 Rationalizing the formula for minimum stock size threshold (B_{MSST}) in management control rules.
P. KLEIBER
(April 2008)

16 Shark deterrent and incidental capture workshop, April 10-11, 2008.
Y. SWIMMER, J. H. WANG, and L. McNAUGHTON (comps. and eds.)
(November 2008)

17 North Pacific blue shark stock assessment.
P. KLEIBER, S. CLARKE, K. BIGELOW, H. NAKANO, M. MCALLISTER, and Y. TAKEUCHI
(February 2009)

18 Clinical observations of ocular disease in Hawaiian monk seals.
M. T. HANSON, A. A. AGUIRRE, and R. C. BRAUN
(March 2009)

19 American Samoa as a fishing community.
A. LEVINE, and S. ALLEN
(July 2009)