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An Approach to Measuring the Economic Effects of Fishery Allocations with an Application to Gulf of Mexico Red Grouper

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1. Overview of the Economic Framework for Fishery Allocation Decisions

1.1. Introduction

The growing competition for seafood and recreational opportunities has encouraged the Gulf of Mexico Fishery Management Council to consider the implications of redistributing the red grouper resource between the commercial and recreational sectors. Crucial to this policy issue is who gets the fish and how much of the fish they get since what is beneficial to one sector may not necessarily be the best for society (Green, 1994). Economics is uniquely suited to assist with this endeavor since it offers a sound framework to allocate a scarce resource among competing uses and offers a common currency to evaluate allocation tradeoffs. According to economic theory, society's benefits will be maximized by reallocating the total allowable catch (TAC) such that the incremental net value afforded to one sector by increasing its allocation matches the marginal net value forgone by the other sector as its allocation is reduced.

In addition, because the value to commercial fishermen comes from their profits and the value to recreational fishermen is derived from the quality of the recreational experience, there is a need to develop a common denominator to assess and compare benefits of consumption and enjoyment across sectors (Green, 1994). Economics offers such a currency or common denominator. This common denominator is the net benefit, which seeks to monetize the well-being of using, consuming or enjoying a limited resource (Green, 1994). As noted by Green (1994) the beauty of economics is that net benefits, when properly measured, reveal the true value of a resource. The use of net benefits as a common currency allows policymakers to consider the economic consequences of alternative allocations.

The objective of this report is to present a simple economic framework to guide allocation decisions and to estimate the economically optimal allocation of the Gulf of Mexico red grouper resource between commercial and recreational sectors. The report is organized as follows. The remainder of chapter one introduces the notion of total and net economic value, discusses how these metrics can be used to make economically sound decisions and discusses the pitfalls of using economic impact analysis to make allocation decisions. Chapter two introduces the conceptual framework for assessing the economic benefits provided by the commercial sector, presents the empirical model and discusses the econometric results. Chapter three introduces the conceptual framework for the recreational sector, presents the empirical model and discusses the econometric results. The final chapter draws on the models developed on chapter two and three to examine the implications of redistributing the red grouper quota.

1.2. Defining Economic Value

Since competing user groups have vested interests in the outcomes of allocation decisions, they often advance distorted economic arguments to secure a larger share of the fish stock (Edwards, 1990). For example, commercial fishermen may characterize recreational fishing as devoid of value since it is primarily a leisure activity (*i.e.*, the "market value" argument) whereas recreational fishermen like to point out that angler's expenditures often exceed the commercial dockside revenue (*i.e.*, the "revenues" argument). As Edwards (1990) correctly points out, these arguments are fraught with biases. The "market value" argument incorrectly presumes that only markets bring about value. Similarly, the "revenues" argument ignores the cost of using other scarce resources in the production process. Given this backdrop, it is useful to review the notion of total and net economic value.

Economic value is an anthropocentric concept shaped by individuals' tastes and preferences (Kahn, 1998). Those goods and services that provide the most satisfaction are valued the most. Therefore, people's willingness to pay for a good or service, such as recreational fishing trip or seafood, defines their total economic value. Since their consumption requires them to forgo spending on other goods and services, their willingness to pay sends strong signals to the market that allow it to prioritize the production and distribution of limited resources among competing uses (Edwards, 1990). Society's well-being is maximized when scarce resources go to those ends that generate the most value to society.

For policy purposes, it is useful to aggregate every person's willingness to pay to derive society's total value for that good or service. Since consumers' willingness to pay often exceeds the actual expenditure for that good or service, they receive a "surplus" in that the value enjoyed by the consumer exceeds the expenditure. Thus, consumer surplus is the net value of the resource. Graphically, the total value is the area under the demand (or willingness to pay) curve whereas consumer surplus is the area between the demand curve and its market price (Figure 1). It is important to recognize that although markets for certain activities such as fishing experiences do not exist, the lack of a market does not preclude anglers from deriving benefits from their experiences. The presence of markets simply facilitates the measurement of consumers' willingness to pay for a good or service (Edwards, 1990).

In addition to consumer benefits, society may derive benefits from the production of goods and services. The net benefit to producers (or producer surplus) is given by the difference between the sale value of the good (or service) minus its production costs. Graphically, the producer surplus is given by the area above the supply (production cost) relationship and the market price. The area underneath the supply function measures the total cost of production (Figure 1). Based on the above, it is clear that revenues alone overestimate net economic value because they ignore the costs of production.

1.3. Net Economic Value: A Common Currency

Net benefits are the difference between gross benefits and costs. The sum of consumer and producer surpluses equals the net benefit to society. In the case of the commercial sector, net benefits encompass consumer surplus from the retail market plus the producer surplus from the harvesting, distribution and processing, wholesale and retail markets. In sport fishing sector, net benefits are derived from the sum of angler consumer surplus and the for-hire producer surplus (Edwards, 1990). These net benefits embody the monetized sum of the surpluses enjoyed by the users in excess of the costs. The change in the net benefit caused by a change in allocation of the resource is called the marginal net benefit.

Clearly, regulators could maximize society's well-being by awarding a larger share of the scarce resource to those sectors that generate higher marginal net benefits. Fishery managers interested in economic efficiency can reallocate the total allowable catch (TAC) such that the incremental marginal net value afforded to one sector by increasing its allocation matches the marginal net value forgone by the other sector as its allocation is reduced. At this point, the economically optimal allocation will be achieved.

1.4. Economic Impact Analysis

Economic impact analyses are often proposed as an alternative way to value fisheries. Economic impact analyses measure primary and secondary industry effects of the fishing activity in terms of spending, income and employment (Green, 1994). Typically, these studies compare gross retail expenditures by recreational fishermen with dockside revenues earned by commercial fishermen to ascertain the value of the resource to the recreational and commercial sectors. For instance, assume that a study shows that recreational gross expenditures for a certain species are $30 million and commercial dockside gross revenues are $5 million. These types of analyses argue that since the recreational sector has a greater economic impact, then it should receive a larger share of the catch.

Unfortunately, these analyses are not based on true net economic benefits. Gross recreational expenditures are costs to recreational fishermen that detract from the total benefits that they receive from recreational fishing. True economic benefits (*i.e*. their consumer surplus) include the net gains to recreational fishermen after deducting their costs of fishing. Impact analyses correctly note that expenditures represent gross incomes to the sellers of recreational fishing supplies and services. However, true economic benefits (*i.e*., their producer surplus) include the net gains to sellers of fishing supplies and services after deducting their costs of production. Therefore, it is impossible to determine if the recreational benefits associated with expenditures are greater or less than the benefits generated by commercial production. Similarly, we have already noted that dockside revenues are not a true measure of benefits to the commercial fishery because they do not account for costs of production.

Another limitation of the economic impact approach is that changes in policies, such as an allocation, may result in a shift in expenditures to other sectors. For example, restricting the commercial catches of one species may result in new expenditures for other commodities such as poultry. Thus, expenditures are transferred between sectors but there is no net loss to society.

1.5. References

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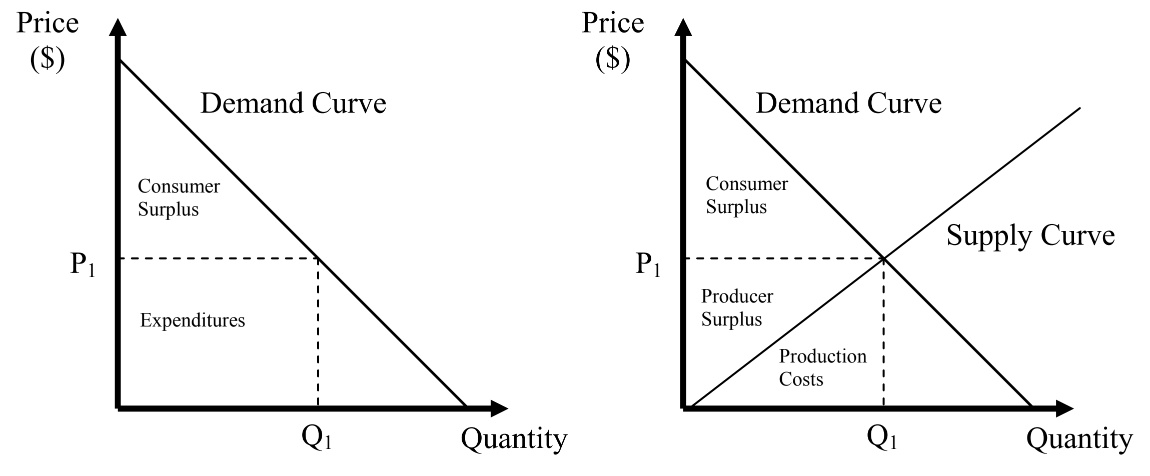

Figure 1: Consumer and producer surplus.

2. Modeling the Economic Value of Red Grouper to the Commercial Sector

2.1. Introduction

The assessment of economic value of the red grouper resource for allocation purposes is a complex endeavor due to the multispecies nature of the fishery. Fishing gears' limited ability to target among the numerous simultaneously caught species makes it difficult to determine the net value of each species. Furthermore, constraints on the multiproduct harvesting technology, such as the rationing of outputs (e.g., quotas), circumscribes fishing firms' production choices and responses. Resource restrictions reduce the economic performance of fishing firms because they cannot produce at lowest cost. Even in the presence of transferable quotas, fishing firms may not easily reorganize their product portfolios to match quota holdings due to limited product transformation possibilities. Therefore, greater care must be given to the estimation of species specific marginal values since constraints on the multiproduct harvesting technology influence the generation of economic benefits.

This chapter develops and estimates an economic model that values the net contribution of red grouper while explicitly recognizing the multiproduct nature of the commercial harvesting sector. The remainder of the chapter provides a brief overview of the regulatory history, introduces a framework for assessing the economic benefits provided by the commercial sector, describes the empirical model and econometric results and finally calculates the marginal net benefit schedule for the commercial sector.

2.2. Regulatory history

The shallow water grouper complex occurs primarily in the eastern Gulf of Mexico. Red, gag, black, scamp, yellowfin, yellowmouth, rock hind, and red hind grouper comprise the shallow-water grouper complex.[1] Their affinity for reef and hard bottom areas makes them susceptible to fixed gears such as longlines, vertical lines, and traps (Moe 1969; Bullock and Smith 1991). Red grouper is the most important component of the shallow-water grouper complex, followed by gag and black grouper. In 2004, the commercial fleet landed about 10.3 million pounds of shallow water groupers (whole weight) valued at $22.1 million dollars. Red grouper accounted for 65.8% of the landings and 60.2% of the revenues and gag accounted for 29.6% of the landings and 34.5% of the revenues. Black grouper accounted for approximately 5% of the landings and revenues. Longlines alone accounted for about 60% of the total red grouper landings. Vertical line and traps were responsible for about 25% and 13% of red grouper landings, respectively.

Federal and state agencies share the responsibility for managing the shallow water grouper complex. In 1984, the Gulf of Mexico Fishery Management Council (GMFMC) implemented the Fishery Management Plan for the Reef Fish Resources (FMP) to protect and rebuild declining reef fish stocks.[2] This FMP banned the use of fish traps, roller trawls and powerhead-equipped spear guns within sensitive inshore areas and mandated the National Marine Fisheries Service (NMFS) to develop a data reporting requirement for the fishery. In 1990, Amendment 1 established that reef fish stocks should achieve a 20% spawning stock biomass per recruit by January 2000. To achieve this goal, the GMFMC set a 20-inch total length minimum size limit on red, gag, black, yellowfin and Nassau groupers, and instituted an 11 million pound grouper quota, which was subdivided into a 9.2 million pound shallow-water

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[1] The deep-water grouper complex consists of snowy, yellowedge, speckled hind, warsaw, and misty grouper. The harvesting of Nassau and goliath grouper is banned.

[2] Florida's Marine Fisheries Commission (FMFC) is responsible for managing reef-fish resources within state waters. In 1985, it established a minimum size limit of 18 inches total length for red, gag, yellowfin, Nassau and Goliath grouper.

grouper and 1.8 million pound deep-water grouper quota. In addition, the amendment imposed geographic restrictions where longline and buoy gears could operate, and established reef fish vessel permits and fish trap permits. A maximum of 100 traps per permit holder was allowed.

In 1992, Amendment 4 established a moratorium on the issuance of new reef fish permits for a maximum of three years to stabilize fishing effort while the Council considered a more extensive effort control mechanism. This amendment allowed permit transfers between vessels owned by the same permit holder, and between owners when the permitted vessel was transferred.

In 1996, U.S. Congress concerned about the health of the nation's fisheries passed the Sustainable Fisheries Act (SFA). The SFA mandated that harvest rates be commensurate with the biological productivity of the stocks. SFA required fishery managers to rebuild all over-fished fisheries and capped fishery harvests at the maximum sustainable level. The Act also mandated the assessment and the mitigation, to the extent practicable, of bycatch and bycatch mortality. In addition, the SFA required that essential fish habitat be defined and protected. Regulatory protection of essential fish habitat (EFH) resulted in the regulatory amendment of 2000, which afforded greater protection to reef-fish stocks, shallow-water grouper complex species. Specifically, the regulatory amendment mandated an increase in the minimum total length limit of gag from 20 to 24 inches; prohibited the harvest and sale of red, gag, black grouper between February 15 and March 15 during the peak of the gag grouper spawning season; and established two marine reserves to protect reef fish spawning aggregations.

In October 2000, NOAA declared the red grouper resource to be overfished and undergoing overfishing, which resulted in the development of Secretarial Amendment 1, which became effective in July 2004. Secretarial Amendment 1 established a rebuilding plan for red grouper, which relied on a two-tiered commercial shallow water grouper quota. Under the two-tiered quota system, the shallow water grouper fishery (which includes red grouper) would close when either the aggregate shallow-water grouper quota of 8.8 million pounds, gutted weight, or the red grouper quota of 5.31 million pounds, gutted weight, was reached.[3] In addition, it established a commercial quota of 1.02 million pounds, gutted weight, for the deep-water groupers and a commercial quota of 0.44 million pounds, gutted weight, for tilefish.

Following the implementation of the two-tiered quota system, fishing seasons for both shallow and deep-water groupers became shorter. For instance, in 2004, the shallow water grouper fishery was closed on November 15, whereas in 2005 it was closed on October 10. Similarly, in 2004, the deep-water groper fishery was closed on July 15, while in 2005 it was closed on June 23. Concerns about the adverse social and economic impacts of progressively shorter fishing seasons and derby-style fishing led to the implementation of an emergency rule on March 3, 2005. Under this emergency rule, a commercial trip limit of 10,000 pounds, gutted weight, was implemented for deep-water groupers and shallow water groupers combined. The trip limit was subsequently reduced to 5,500 lbs depending on the season and quota utilization thresholds.

The interim stepped-down trip limit system was phased out in January 2006, when a regulatory amendment established a permanent, aggregate shallow-water and deep-water grouper trip limit of 6,000 pounds, gutted weight. On February 7, 2007, the use of fish traps in the Gulf reef fishery was prohibited.

Presently, the GMFMC is considering a new amendment to the reef-fish fishery management plan. An important component of this amendment is the development of a

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[3] The State of Florida automatically closes the red grouper fishery in state waters when federal closures occur.

multispecies individual transferable quota program to provide the opportunity for a year around fishery, enhance business planning and financial stability and promote safe fishing operations.

2.3. Conceptual model

Harvesting sub-sector

Consider that the longline and vertical line fleets are composed of profit maximizing multioutput (multispecies) firms and that each firm's indirect short-run profit function is given by

(2.1) $$\pi(p,w;K)=\sum_{i=1}^{n}p_i y_i(p,w;K)-\sum_{j=1}^{m}w_j x_j(p,w;K)$$

where π is the restricted (short-run) profit function, p_i is the price of species i, y_i is harvest of species i, w_j is the price of input j, and x_j in the amount of input j used. K is the quasi-fixed capital stock. As is customary in production analysis, we assume that the profit function is non-decreasing in output prices and fixed factors, non-increasing in input prices, linear homogenous and convex in prices, concave in fixed quantities, and continuous and twice differentiable.

The restricted profit function measures quasi-rent. Quasi-rent is the payment to factors of production which are temporarily in fixed supply. The short-run nature of the model is not only conditional of the quasi-fixed capital stock, but is also conditional on the available fish biomass. Thus, changes in the capital stock and resource biomass will influence the profitability of the industry.

Output supply and factor demand functions are obtained via Hotelling's lemma,

(2.2) $$\frac{d\pi(p,w;K)}{dp_i}=y_i(p,w;K)$$

(2.3) $$\frac{d\pi(p,w;K)}{dw_j} = -x_j(p,w;K)$$

These supply and demand functions describe the optimal adjustment of outputs and inputs in response to changes in output and input prices.

Because the focus of this analysis revolves around the redistribution of the red grouper resource among competing interests, we assume that the total allowable catch (TAC) is composed of a total allowable commercial catch (TACC) and a total allowable recreational catch (TARC). To investigate the welfare impact of imposing a quota we need to incorporate this additional constraint in the profit function.

Following Vestergaard (1999), suppose that fishery managers impose a commercial harvesting quota on red grouper, TACC, such that $TACC \leq y_1$. Fulginiti and Perrin (1993) describe the relationship between a quota-constrained quasi-rent function and an unconstrained quasi-rent function using the concept of virtual price. Virtual price, p_v, is the price that would induce an industry (or firm) to freely produce at the desired quota level.

Mathematically, the virtual price is given.

(2.4) $$p_v = (p_1 - \lambda_1)$$

where p_1 is the output price and λ_1 is the unit quota rent for red grouper (output 1). Lambda expresses the marginal valuation of output 1.

Formally,

(2.5) $$\frac{\partial \pi}{\partial p_v} = TACC$$

At the virtual price for quota 1, the quota quasi-rent function must equal to the quota-free quasi-rent function

(2.6) $$\pi(p_1, p_h; TACC, K)^{TACC} = \pi(p_v, p_h, w; K)$$

P_h is the *n-1* vector of other output prices.

Alternatively, the quota quasi-rent function can be expressed as

$$\begin{aligned}\pi(p_1, p_h; TACC, K)^{TACC} &= \pi(p_v, p_h, w; K) + (p_1 - p_v)\ TACC \\ &= \pi(p_1 - \lambda_1, p_h, w; K) + \lambda_1\ TACC\end{aligned} \tag{2.7}$$

Rewriting (2.7) we get

$$\begin{aligned}\pi(p, w; TACC, K)^{TACC} &= \sum_{i=2}^{n} p_i y(p_1 - \lambda_1, p_h, w; K) + \lambda_1\ TACC \\ &- \sum_{j=1}^{m} w_j x_j (p_1 - \lambda_1, p_h, w; K)\end{aligned} \tag{2.8}$$

Applying Hotelling's lemma, we get the output and input functions

$$\frac{\partial \pi^{TACC}}{\partial p_i} = y_i (p_1 - \lambda_1, p_h, w; K)\ \forall\ \mathrm{i} \geq 2 \tag{2.9}$$

$$\frac{\partial \pi^{TACC}}{\partial w_j} = -x_j (p_1 - \lambda_1, p_h, w; K) \tag{2.10}$$

Differentiating with respect to the quota levels, we obtain the inverse derived demand for quota. The difference between market output price and the virtual price is the quota rent.

$$\frac{\partial \pi^{TACC}}{\partial TACC} = \lambda_1 (p, w; TACC, K) \tag{2.11}$$

The industry's (or firm's) inverse derived demand for quota captures the optimal adjustment in inputs used and other outputs as the quota changes. It indicates by how much the industry's implicit marginal valuation of quota must change for vessels to want to hold an additional unit of quota (Squires and Kirkley, 1996; Just et al, 2004).

Now let us turn our attention to estimating welfare impacts. Using the inverse derived demand for quota relationship, we can obtain the quasi-rent from either the output or input market when a quota is imposed. Drawing on equation (2.9), we can estimate the producer surplus (and quasi-rent) from the output market

$$PS^{TACC} = \int_{p_1^0}^{p_1-\lambda_1} \frac{\partial \pi}{\partial p_1}(p,w;K,S)dp_1 + \int_{p_1-\lambda_1}^{p_1} TACCdp_1 = \int_{p_1^0}^{p_1-\lambda_1} y_1(p,w;K,S)dp_1 + \int_{p_1-\lambda_1}^{p_1} TACCdp_1$$

$$(2.12) \qquad = \pi(p_1-\lambda_1, p_h, w;K,S) + \lambda_1 TACC = \pi^{TACC}(p,w;TACC,K,S)$$

Figure 1 shows the producer surplus in the output market. The producer surplus is the sum of the harvest surplus (area A) and quota surplus (area B). Mathematically, the harvest surplus and quota surplus is can be estimated by solving the first and second integral of equation (2.12), respectively.

Alternatively, we can also calculate changes in quasi-rent in input space. The area under the implicit derived demand for quota up to the quota level can also be used to measure estimate quasi-rent (Figure 2). The producer surplus is the sum of the harvest surplus (area C) and quota surplus (area D). This is true, because the inverse derived demand for quota reflects the industry's valuation of quota as the quota level varies. Mathematically,

$$(2.13) \quad PS^{TACC} = \int_{0}^{TACC_1} \lambda_1(p,w;TACC,K)dy_1 = \int_{0}^{TACC_1} \frac{\partial \pi}{\partial TACC} dy_1 = \pi^{TACC}(p,w;TACC,K)$$

Using the above framework, we can estimate producer surplus or quasi-rent gains (or losses) under different TACC levels (or commercial-recreational allocation scenarios). Next, we consider consumer benefits.

Consumer sub-sector

Catch restrictions not only impact the profitability of harvesters, but also impact consumers who have to pay higher seafood prices. Thus, changes in consumer surplus must be considered when allocating smaller harvest levels between the commercial and recreational sectors. To examine the changes in consumer surplus, we propose estimating a wholesale demand relationship for red grouper. Mathematically,

(2.14) $P_{redgrouper} = f(P_{complements}, P_{substitutes}, Income, Population\ size, Own\ landings \mid TACC)$

Potential substitutes for red grouper would include other domestic species such as other shallow water groupers, snappers and mahi-mahi and fresh and frozen grouper imports.

To estimate changes in consumer surplus, we take as the base the most recent year available (i.e., 2005) and set average values for the price of complement and substitutes, income, and population size. Then, we would estimate consumer surplus by changing the value of own landings to reflect different TACC levels. A similar approach is proposed for the harvesting sub-sector, however, instead of using demand curves we would be using the red grouper output supply function.

Finally, we would combine both quasi-rent and consumer surplus at each TACC level and compare how these net benefits change as we reduce the TACC. The optimal static allocation occurs when the marginal benefit to the commercial sector equals the marginal cost (marginal net benefits forgone) to the recreational sector.

2.4. Empirical Model

Harvesting sub-sector

In developing the empirical model, we assume that fishermen seek to maximize profits in two stages (Squires and Kirkley, 1991). In the short-run, fishermen advance their welfare by choosing their revenue maximizing catches conditional on existing fixed factor levels, weather, habitat and resource abundance constraints and relative output prices. In other words, we assume that revenue maximization is an appropriate behavioral hypothesis since fishing vessels cannot readily change input levels during the harvesting process. In the long-run, fishermen maximize profits by selecting the optimal capital endowment.

In this study, we assume that vertical line and longline vessels maximize short-run profits (revenue) by selecting the optimal species composition and level of catch conditional upon quasi-fixed factors (Kirkley and Strand, 1988, Squires and Kirkley, 1991). The vertical line gear encompasses both handline and bandit gear vessels. Following Kirkley and Strand (1988), we adopt the non-homothetic generalized Leontief quasi-rent function. Mathematically,

$$(2.15)\quad \pi(p;K)=\sum_{i=1}^{n}\alpha_i p_i K^2+\sum_{i=1}^{n}\beta_{ij}(p_i p_j)^{1/2}K$$

where π is the quasi-rent function, *K* is the quasi-fixed input, and p_i is output prices of species *i*. Symmetry is imposed by setting $\beta_{ij}=\beta_{ji}$ for $i\neq j$. Although there are several flexible functional forms available to approximate fishermen's profit function, we selected the non-homothetic generalized Leontief functional form because it places few restrictions on the underlying structure of the technology and permits the examination of important properties such as separability and non-jointness.[4] Another consideration was that this functional form permits the estimation of output levels rather than output shares like in the case of the translog functional form (Kirkley and Strand, 1988). Modeling output levels rather than shares is appealing because it is more intuitive to decision-makers and readily lends itself to the estimation marginal benefit schedules.

Applying Hotelling's lemma, we obtain the associated input-compensated supply equations,

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[4] However, this functional form imposes linear homogeneity in prices (Kirkley and Strand, 1988).

$$(2.16)\quad \frac{\partial \pi}{\partial p_i} = y_i = \alpha_i K^2 + \beta_{ii} K + \sum_{j \neq i} \beta_{ij} \left(\frac{p_j}{p_i}\right)^{1/2} K$$

The supply equations are input-compensated because they are conditional on the fixed input.

To investigate the welfare changes of introducing TACC for red grouper, we replace the red grouper ex-vessel price by its virtual price. After rearranging the terms, we obtain the fleet's derived demand for quota

$$(2.17)\quad \lambda_1 = p_1 - \left[\frac{\sum_{j \neq 1} \beta_{1j} p_j^{1/2} K}{TACC - \alpha_1 K^2 - \beta_{11} K}\right]^2$$

where the first tem is the red grouper dockside price and the second term is its virtual price. To estimate the quasi-rent we first integrate equation (2.17) from zero to quota level. Because fisheries agencies set the quota, lambda adjusts at the margin rather than the quota (Squires and Kirkley, 1996).

Estimation:

We specified the non-homothetic generalized Leontief revenue function as

$$(2.18)\quad \begin{aligned} \pi(p;K) = {} & \sum_i \alpha_i p_i K^2 + \sum_i \sum_j \beta_{ij} (p_i p_j)^{1/2} K + \sum_i \sum_k \delta_{ik} d_k p_i K + \sum_i \sum_l \varepsilon_{il} e_l p_i K + \\ & \sum_i \sum_m \phi_{im} f_m p_i K + \sum_i \sum_n \varphi_{in} g_n p_i K + \sum_i \sum_o \gamma_{io} h_o p_i K + \sum_i \sum_r \eta_{ir} l_r p_i K + \\ & \sum_i \sum_s \kappa_{is} t_s p_i K + \sum_i \sum_u \varpi_{iu} v_u p_i K \end{aligned}$$

where *π(p;K)* is the quasi-rent function, *K* is the quasi-fixed input, and p_i is output prices of species *i*. d_k is the k^{th} of eleven binary variables for months February -December, and e_l is the l^{th} of two binary variables for years 2002 and 2003. 2004 was selected as the base year. f_m is the m^{th} binary variable for landing county and fishing ground. For the vertical line fleet, Bay, Citrus, Franklin, Lee, Escambia, Monroe, Pinellas, Okaloosa and Wakulla counties were selected whereas for the longline fleet, Bay, Manatee, Monroe and Pinellas counties were chosen. The binary variables for month, year and fishing grounds control for changes in the availability and abundance of the targeted stocks. t_s is the monthly accumulated cyclonic energy (ACE) index, which captures intensity and duration of Atlantic named storms and hurricanes occurring during a given season,[5] and v_u is a dichotomous variable for the vertical line fleet only; it takes the value of 1 if bandit gear is used and zero otherwise (i.e., handline gear is used).

G_n, h_o, and l_r are dichotomous variables that capture the presence of three closures. The g_n captures the annual closed season from February 15 through March 15, which has been in effect since 2000 for red, gag, and black grouper. The second closure variable, h_o, captures the closure of shallow water grouper and red grouper fishery on November 15, 2004. The third closure variable captures the closure of the deep-water grouper fishery on July 15, 2004. These closures take a value of 1 when active. The number of days away from port is set as the quasi-fixed input since during the fishing trip capital and labor are effectively fixed. Symmetry was imposed by setting $\beta_{ij}=\beta_{ji}$ for $i \neq j$.

Applying Hotelling's lemma, we obtain the associated input-compensated supply equations

$$\text{(2.19)} \quad \frac{\partial \pi(p;K)}{\partial p_i} = q_i = \alpha_i K^2 + \beta_{ii} K + \sum_{j \neq i} \beta_{ij} \left(\frac{p_j}{p_i}\right)^{1/2} K + \rho\, K$$

where

$$\rho = \sum_k \delta_{ik} d_k + \sum_l \varepsilon_{il} e_l + \sum_m \phi_{im} f_m + \sum_n \varphi_{in} g_n + \sum_o \gamma_{io} h_o + \sum_r \eta_{ir} l_r + \sum_s \kappa_{is} t_s + \sum_u \omega_{iu} v_u$$

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[5] Formally, the ACE index equals the sum of the squares of the maximum sustained surface wind speed (knots) measured every six hours for all named systems while they are at least tropical storm strength.

Data:

Dual specifications rely on output and factor prices and output and input quantities. To model fishermen's revenue maximizing behavior we used the Florida's *Marine Fisheries Trip Ticket* database, which collects trip-level landings, prices, crew size, area fished, county landed, and gear-specific fishing effort. Although we could have used the Fishery Logbook System (FLS) database, which contains trip-level landings and effort information, in conjunction with the Accumulated Landings System (ALS), which includes monthly dockside prices, we decided against it for several reasons. First, the Florida trip ticket program is the only program that collects trip-level prices, which should help capture any price signals (if present). Although, combining FLS and ALS databases can also provide dockside prices, these prices would be at a monthly level rather than at a trip level. Aggregating prices at a monthly level may dampen (or conceal) fishermen's behavioral response to price signals. A second consideration was the wider coverage and finer spatial resolution of the Florida trip ticket relative to the logbook program. Specifically, the Florida trip ticket program distinguishes between inland waters, inshore state waters, offshore state waters, and federal waters whereas the logbook program uses broader Gulf of Mexico statistical grid areas. Furthermore, the logbook only requires fishermen to report catches in federal waters.

Despite the above, the Florida trip ticket database has a major shortcoming. It does not collect cost information. The FLS has an economic add-on which covers about 20% of the commercial fleet operating in the Gulf of Mexico. This economic add-on collects trip-level input prices (or imputed prices) for selected expenditures (e.g., gas, bait, ice, crew payments, food and miscellaneous supplies). Unfortunately, because the FLS allows for the reporting of input usage such as bait, ice, food in various measurement units (e.g., bait is reported in either counts or weight) we cannot develop derived demands for these inputs.[6] However, it is important to note that we can estimate a derived demand for fuel, which is the largest variable cost component. Another consideration is that the crew size variable in the Florida trip ticket database is consistently under-reported. For example, about 80% of the trips with handlines had no information on crew size. Therefore, we cannot link both databases and hope to obtain reliable labor and other input expenses.

In light of the abovementioned, we restricted our analysis to the Florida trip ticket database. We modeled the industry behavior using data from 2002 to 2004. For the vertical line fleet, we specified four species groups: red grouper, other shallow-water groupers, shallow and mid-water snappers and a residual or miscellaneous group, which captured all species not included in the earlier groupings. For the longline fleet, we specified three species groupings, which included red grouper, other shallow water groupers, and a miscellaneous group. We adjusted all output prices to December 2005 prices using the producer price index. To account for the possibility of differing targeting behavior due to changes in relative prices, our sample consisted of all vertical line and longline boats that harvested red grouper at least once during the last four years. Descriptive statistics of the vertical line and longline fleets are presented in tables 1 and 2.

Consumer sub-sector

We continue to work on this section. However, we attempted to estimate a simple annual demand curve for the wholesale prices as a function of disposable income, Gulf of Mexico landings and fresh grouper imports. Table 3 shows descriptive statistics of these variables adjusted by the 2005 consumer price index. Mathematically, the demand function is given by

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[6] Bait costs account for 10-15% of the revenue.

(2.20) $P_{redgrouper} = f(P_{substitutes}, Disposible\ Income, Fleet\ own\ landings)$

Data:

Disposable income, population size, and consumer price index data was obtained from the Bureau of Labor Statistics (BLS) and Bureau of Economic Analysis (BEA).[7] Wholesale prices from the Fulton Market, dockside prices and landings of substitutes and complements were obtained from NOAA Fisheries website. Information on fresh and frozen imports originally came from the Foreign Trade Division of the U.S. Census Bureau.

2.5. Estimation Results

Harvesting sub-sector:

We estimated individual equations separately using ordinary least squares (OLS) and tested for heteroscedasticity using White's test. Based on earlier production work with this specification, we anticipated that the heteroscedasticity would be introduced by the square of the quasi-fixed input variable (Squires and Kirkley, 1991; Campbell and Nicholl, 1994) so we weighted the sample by the quasi-fixed input. This addressed the heteroscedasticity present in the equations for red grouper and other shallow water groupers in the longline model, but it failed to remove any of the heteroscedasticity present in the vertical line model. Given the above and the utility of standardizing both models, we estimated input-scaled output supply functions for both

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[7] See, http://www.bls.gov/cpi/home.htm, http://www.bea.gov/national/nipaweb/Index.asp, and http://www.st.nmfs.gov/st1/market_news/index.html

the longline and vertical line fleets using full information maximum likelihood estimator (Greene, 2000).[8]

The generalized R^2 for the system of equations prior to the correction for heteroscedascity was 79.6% for the vertical line and 57.6% for the longline fleet (Squires and Kirkley, 1991). Space limitation precludes us from discussing parameter estimates in detail; however, Appendices A and B show the parameter estimates and their standard errors for the vertical line and longline models, respectively.

Table 4 shows that yearly, monthly, fishing ground and closure variables, as a group, are statistically significant for the vertical line fleet. Perusal of Appendix A shows that most red grouper parameters of the vertical line fleet conformed to our expectations. For example, the seasonal closure and shallow-water grouper closure were negative and statistically significant suggesting that these closures constrained the production of red grouper. On the other hand, the deep-water grouper closure was positive and statistically significant, suggesting that these closures increased the production of red grouper. The bandit gear variable was positive and statistically significant suggesting that bandit boats are more productive catching red grouper.

Table 5 shows that yearly, monthly, fishing ground and closure variables, as a group, are statistically significant for the longline fleet. Examination of the parameters of the longline red grouper supply function shows that most variables agreed with our expectations. For instance,

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[8] The functional form was presumed to be exact rather than an approximation. We also assumed that the errors are from optimization rather than approximation and applied only to the input-scaled supply equations (Squires and Kirkley, 1991). The issue of zero outputs came up in some instances, creating a limited-dependent variable problem, which can introduce bias and non-normality of the residuals. The procedure of Lee and Pitt (1987) addresses this issue using virtual prices, but it is not computationally feasible with the number of variables in this study (Squires and Kirkley, 1991). A Box-Cox transformation could be used, but we decided against it because a particular form of non-normal disturbances is assumed prior to transformation (Squires and Kirkley, 1991). Thus, we substituted a value of 0.1 for zero when necessary.

the seasonal closure and shallow-water grouper closure were negative and statistically significant suggesting that these closures restrain the harvesting of red grouper. However, the deep-water grouper closure was positive and statistically significant.

Table 6 presents hypothesis tests on the underlying technology. The hypotheses of input and output separability and overall non-jointness-in-inputs were rejected for both the longline and vertical line fleets. The rejection of input-output separability implies that there are specific interactions between input and output combinations. Therefore, changes in relative prices can influence the optimal combinations of capital and labor devoted to the harvesting process. The rejection of input-output separability also implies that the technology does not allow for the creation of a single composite input and single composite output. Thus, fishery managers should consider management measures that require lower levels of species aggregation such as species group or species-specific quotas.

The rejection of overall non-jointness-in-inputs indicates that all inputs are required to produce all outputs. It also indicates that the harvesting process is interrelated. Hence, each species' production process cannot be regulated independently because of the presence of spillover effects on other species. For instance, establishing a quota for any of these individual species may lead to the overexploitation of an unregulated substitute species. If the harvesting process was not joint-in-inputs then single species would be appropriate since regulations would not impact the production process of the other species. Species-specific non-jointness-in-inputs was rejected for all species, except for the other shallow-water groupers for the longline fleet. The rejection of species-specific non-jointness-in-inputs indicates that the production of any given species is affected by the relative prices and quotas of the other jointly-caught species.

This study also examined own-price and cross price elasticities of supply. Price elasticities of supply measure the responsiveness of the quantity supplied due to a change in price. The diagonal elements in Tables 7 and 8 represent the own-price elasticities, and the off-diagonal elements represent the cross-price elasticities. The mixed pattern of complementarity and substitutability suggests that single species management may have unintended consequences on the rest of the fishery. All own-price elasticities for the vertical line and longline fleets were positive; however, they were only statistically significant for other shallow-water grouper, shallow and mid-water snapper, and miscellaneous species groupings in the vertical line fleet. The residual species group was the only statistically significant own-price elasticity for the longline fleet. In both the vertical line and longline fleets, the residual group was found to be a statistically significant substitute for red grouper. Thus, if managers imposed a quota on red grouper, fishermen would be able to adjust their catch mix by landing more of the miscellaneous species. All scale elasticities were positive and statistically significant.

<u>Consumer sub-sector:</u>

As noted above, we continue to work on this section. However, we attempted to estimate a simple <u>annual</u> demand curve for the wholesale prices as a function of disposable income, Gulf of Mexico landings and fresh grouper imports. We attempted an annual model rather than monthly model to make it easier to examine welfare changes due to quotas. Unfortunately, because we don't have long time series of seafood imports, this severely limited our ability to incorporate as many explanatory variables as we had hoped (i.e., lack of degrees of freedom).

The estimation was conducted in two steps. First, we regressed monthly red grouper wholesale prices (using NOAA prices from Fulton Market) against Gulf of Mexico red grouper ex-vessel prices and found that without intercept, the slope was 1.61 suggesting a 61% mark-up for whole fish. Second, because we wanted to estimate an annual welfare loss from reducing the red grouper commercial quota, we regressed imputed annual wholesale prices (i.e., ex-vessel prices times 1.61) over disposable income, prices imported fresh imports and Gulf of Mexico red grouper landings using OLS. Parameter estimates are shown in Table 9. The equation was statistically significant at the 0.05 level (F-value was 5.26). The adjusted R^2 for this regression was 48%. Examination of the parameter estimates shows that none of them were statistically significant suggesting that red grouper flexibilities are inelastic.

2.6. Simulation

In order to examine the potential gains (or costs) from redistributing the red grouper TAC, we constructed a simple model to estimate the marginal benefit to the commercial sector as a function of the TAC. The marginal benefit curve captures the commercial sector's willingness to pay for holding an additional unit of quota for a given year. In other words, the marginal benefit curve shows how much the commercial sector is willing to pay for renting additional units of red grouper quota. The rental price differs from the ex-vessel price in that the value to the commercial sector is given by the net revenue (revenues in excess of operating costs) rather than by the gross revenue. In multispecies fisheries, the commercial sector's red grouper's quota rental price may also be influenced by fishing firms' limited ability to modify their catch composition. In this instance, the marginal value of holding an additional unit of quota, may be capturing the additional net revenue derived from catching the other jointly-caught species, such as gag and black grouper, which would be forgone if the red grouper allocation was reduced.

To develop the marginal benefit schedule, we undertook the following steps. First, in the trip level red grouper supply equation, we substituted the ex-vessel red grouper price by its virtual price ($p_v = (p_1 - \lambda_1)$). The virtual price is the marginal value of the red grouper resource since it captures that the commercial sector's willingness to pay for holding an additional unit of quota given the existing TAC. Second, we simulated trip level harvests by increasing the magnitude of λ from \$0 to \$4 using 2003 Florida Trip Ticket data. This allowed us to trace each vessel's trip level marginal benefit schedule. Because the monotonicity requirement of the regulatory conditions was not always satisfied (i.e., meaning that the predicted harvest levels were not always positive in the relevant range) we set those negative and/or non-real observations equal to zero. Last, we aggregated all of the well-behaved observations from both the longline and vertical line fleets to obtain a marginal benefit schedule for the commercial sector. We ignored the trap sector because the Council phased them out in 2007. Since the analysis only included the longline and vertical line sectors and the number of well-behaved observations was below the TAC, we randomly selected additional trips (i.e., some trips were counted twice) until these two gears exhausted the TAC.

For the purposes of this analysis, we calculated the marginal value schedule for red grouper assuming that the commercial sector would be allowed to harvest the entire TAC (i.e., 6.56 million pounds of gutted weight). However, other schedules could have been constructed by assuming different starting TAC levels. Figure 3 shows how the marginal benefit relationship (\$/lb of whole weight) varies as a function of the TAC. The marginal benefit schedule ranges from \$0 to \$3.38. When the commercial sector receives the entire TAC (i.e., when TACC and TARC ~6.56 m lbs gutted weight), the marginal benefit is zero and the quasi-rent is \$10.2 million. At the current TACC of 5.31 m. lbs whole weight, the marginal benefit increases to \$0.95 and the quasi-rent decreases to \$ 9.58 million.[9]

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[9] The quota for red grouper is 5.31 million pounds when expressed as gutted weight. We multiplied by a conversion factor from gutted to whole of 1.18 to estimate whole weight.

Table 10 shows the marginal benefit and quasi-rent for a suite of potential harvest allocations. These values will be used later in chapter 4 to find the optimal re-allocation of the TAC. As noted earlier, the economically optimal reallocation will be given where the marginal benefit at any given allocation is equal across the different sectors.

2.7. References

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Figure 1: Producer surplus in output market.

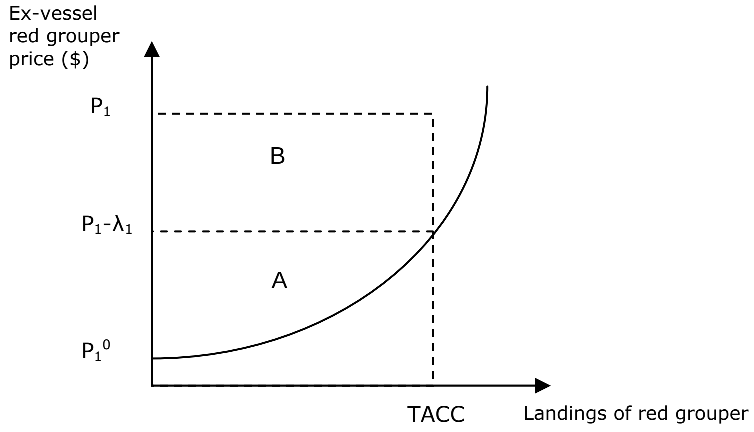

Figure 2: Producer surplus in input market.

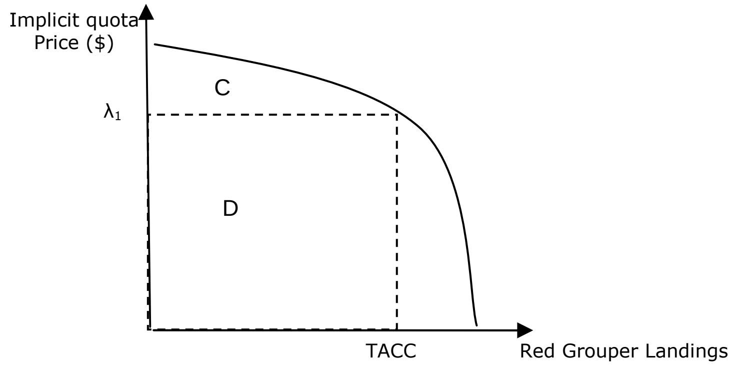

Figure 3: Marginal Benefit Curve for the Commercial Sector.

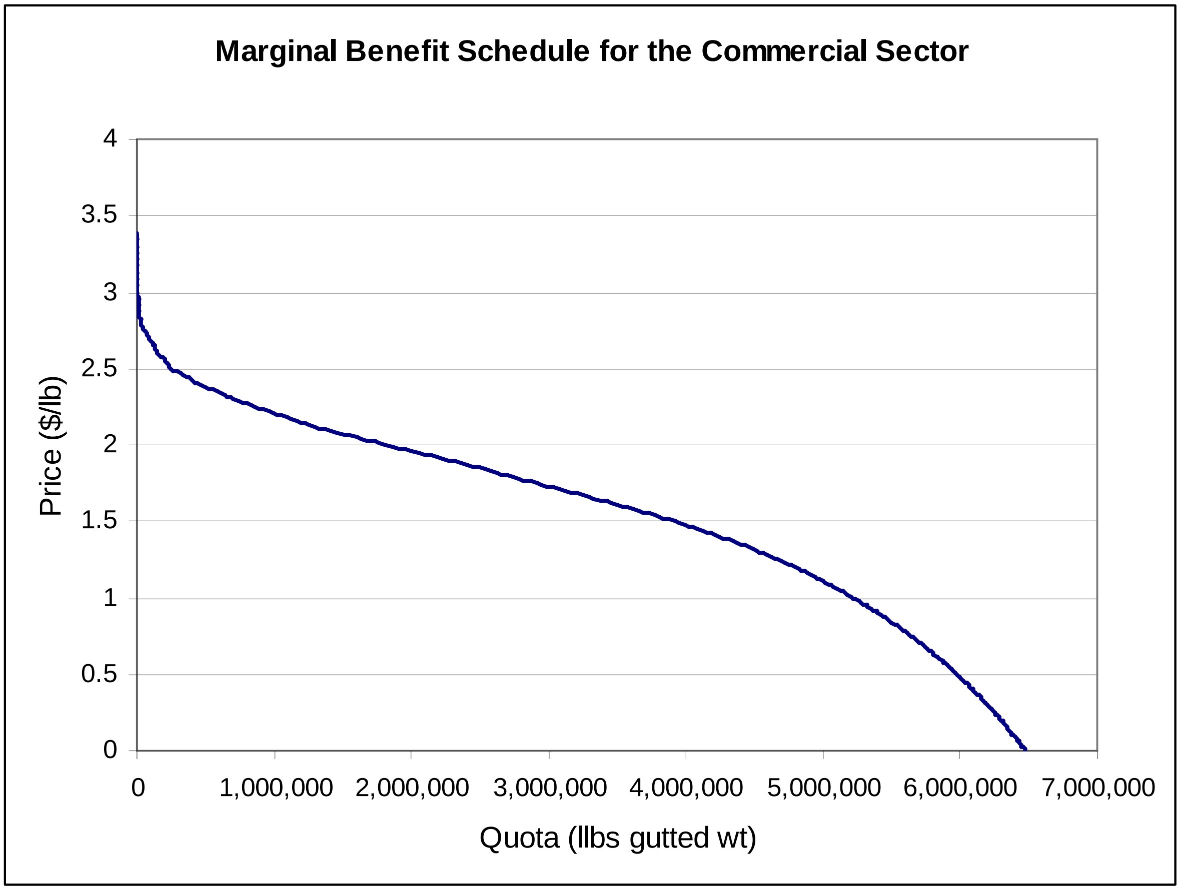

Table 1: Descriptive statistics of the vertical line fleet.

Variable	Mean	Std. Dev.	Min	Max	N
Red grouper landings per trip (lbs)	209.11	432.32	0.10	94,89.00	28,770
Other Shallow-water grouper landings per trip (lbs)	229.03	532.15	0.10	11,736.00	28,770
Shallow and mid-water snapper landings per trip (lbs)	317.21	672.77	0.10	7,599.00	28,770
Residual species landings per trip (lbs)	214.59	507.38	0.10	13,752.00	28,770
Price of red grouper ($/lbs)	1.98	0.21	0.42	4.66	28,770
Price of other shallow water grouper ($/lbs)	2.45	0.22	0.51	3.39	28,770
Price of deep-water grouper ($/lbs)	2.00	0.33	0.32	3.68	28,770
Price of residual species group ($/lbs)	1.13	0.37	0.14	4.21	28,770
Quasi-fixed input (days)	3.22	2.49	1.00	30.00	28,770

Table 2: Descriptive statistics of the longline fleet.

Variable	Mean	Std. Dev.	Min	Max	N
Red grouper landings per trip (lbs)	2,369.04	2,403.51	0.10	18,836.00	4,335
Shallow-water grouper landings per trip (lbs)	870.03	1,489.09	0.10	13,577.00	4,335
Residual species landings per trip (lbs)	1,111.39	2,159.83	0.10	20,688.00	4,335
Price of red grouper ($/lbs)	2.28	0.25	1.50	3.25	4,335
Price of shallow-water grouper ($/lbs)	2.81	0.29	0.97	3.65	4,335
Price of residual species group ($/lbs)	1.65	0.54	0.21	20.00	4,335
Quasi-fixed input (days)	8.07	4.19	1.00	25.00	4,335

Table 3: Descriptive statistics of the wholesale demand.

Variable	Mean	Std. Dev.	Min	Max	N
Wholesale price of red grouper ($/lbs)	3.51	0.18	3.22	3.93	15
Import price of fresh grouper ($/lbs)	1.32	0.15	1.10	1.57	15
Disposable income ($)	27.67	1.90	25.25	30.53	15
Gulf of Mexico landings (million lbs)	6.18	0.85	4.68	7.52	15

Table 4: Statistical significance of group dummies for the vertical line fleet.

Fleet	Hypothesis	χ^2	Prob> χ^2	Outcome (α=0.05)
Vertical line	Yearly dummies	166.37	<.0001	Reject null
	Monthly dummies	1332.2	<.0001	Reject null
	Fishing ground dummies	2679.8	<.0001	Reject null
	County landed dummies	9713.6	<.0001	Reject null
	Seasonal closure dummies	722.67	<.0001	Reject null
	Shallow-water grouper closure dummies	192.30	<.0001	Reject null
	Deep-water grouper closure dummies	247.84	<.0001	Reject null
	ACE dummies	1.88	0.7583	Accept null
	Bandit gear dummies	49.07	<.0001	Reject null

Table 5: Statistical significance of group dummies for the longline fleet.

Fleet	Hypothesis	χ^2	Prob> χ^2	Outcome (α=0.05)
Longline	Yearly dummies	16.71	0.0104	Reject null
	Monthly dummies	95.25	<.0001	Reject null
	Fishing ground dummies	480.03	<.0001	Reject null
	County landed dummies	341.58	<.0001	Reject null
	Seasonal closure dummies	103.62	<.0001	Reject null
	Shallow-water grouper closure dummies	46.05	<.0001	Reject null
	Deep-water grouper closure dummies	19.14	0.0003	Reject null
	ACE dummies	1.00	0.8024	Accept null

Table 6: Hypothesis tests of the technological structure of the longline and handline fleets.

Fleet	Hypothesis	χ^2	Prob> χ^2	Outcome (α=0.05)
Vertical line	Input-output separability	285.88	<.0001	Reject null
	Non-jointnes in inputs			
	Overall	283.04	<.0001	Reject null
	Red grouper	66.28	<.0001	Reject null
	Shallow-water grouper	146.32	<.0001	Reject null
	Shallow and mid-water snappers	183.72	<.0001	Reject null
	Miscellaneous species	116.19	<.0001	Reject null
Longline	Input-output separability	92.72	<.0001	Reject null
	Non-jointnes in inputs			
	Overall	8.78	0.0324	Reject null
	Red grouper	8.41	0.0149	Reject null
	Shallow-water grouper	2.13	0.3441	Accept null
	Miscellaneous species	6.86	0.0324	Reject null

Table 7: Input-compensated own and cross price and scale elasticities for the vertical line fleet (standard errors in parenthesis)

Prices and effort	Elasticity			
	Red grouper	Shallow-water grouper	Shallow and mid-water snappers	Miscellaneous species
Red grouper	0.06	0.11	0.08	-.26*
	(0.10)	(0.10)	(0.05)	(0.03)
Shallow-water groupers	0.08	0.66*	-0.75*	0.00
	(0.07)	(0.10)	(0.06)	(0.04)
Shallow and mid-water snappers	0.05	-0.65*	0.76*	-0.17*
	(0.03)	(0.05)	(0.07)	(0.03)
Miscellaneous species	-0.45*	0.00	-0.45*	0.90*
	(0.06)	(0.09)	(0.09)	(0.10)
Effort	0.01	0.27**	0.15	1.20*
	(0.08)	(0.14)	(0.20)	(0.26)

Significance levels: 0.01,0.05** and 0.1****

Table 8: Input-compensated own and cross price and scale elasticities for the longline fleet (standard errors in parenthesis).

Prices and effort	Elasticity		
	Red grouper	Shallow-water grouper	Miscellaneous species
Red grouper	0.34*** (0.19)	-0.25 (0.19)	-0.09** (0.04)
Shallow-water groupers	-0.54 (0.42)	0.50 (0.42)	0.04 (0.70)
Miscellaneous species	-0.28** (0.11)	0.06 (0.09)	0.22** (0.10)
Effort	0.70* (0.19)	0.99* (0.24)	1.59* (0.30)

Significance levels: 0.01,0.05** and 0.1****

Table 9: Parameter estimates for red grouper annual wholesale demand function (N=15).

Parameter Estimate	Estimate	Std. Error	t Stat	P-value
Constant	1.79	3.23	0.55	0.59
Import Price	1.08	0.94	1.15	0.28
Disposable income	0.02	0.07	0.29	0.78
GOM red grouper landings	-0.05	0.04	-1.08	0.30

Table 10: Quasi-rent and marginal values under various allocations

Allocation (gutted weight lbs)	Marginal Benefit ($/lb)	Total Benefit ($ million)
0	3.38	0
500,000.00	2.38	1.276
1,000,000.00	2.21	2.421
1,500,000.00	2.07	3.488
2,000,000.00	1.96	4.496
2,500,000.00	1.85	5.449
3,000,000.00	1.73	6.343
3,500,000.00	1.61	7.178
4,000,000.00	1.48	7.950
4,500,000.00	1.32	8.649
5,000,000.00	1.11	9.258
5,500,000.00	0.84	9.749
6,000,000.00	0.48	10.085
6,477,020.00	0	10.206

3. A Hedonic Model of Value in the Charter Boat Market

3.1. Introduction

There is a considerable amount of research on the value of sportfishing harvest (Johnston, et al., 2006). The research aims to uncover information about angler's willingness-to-pay (WTP) by direct elicitation (contingent valuation) or by observing the relative opportunity cost of access to different harvest characteristics (travel cost models). In either case, however, the valuation measure is not derived from actual market prices. Rather, a constructed market price or a proxy "price" is assumed to vary directly with willingness-to-pay. For example, applications of the travel cost model infer access and harvest values based on the proxy of distance and travel time to fishing sites. In this case, however, estimated values are only as accurate as the calculated proxy prices.[10] The problems in measuring accurate "travel prices" are well-known (Englin and Shonkwiler, 1995, Landry and McConnell, 2007, Lew and Larson, 2005, Randall, 1994).

This paper reports on an alternative, hedonic, strategy to estimate the value of sportfishing experiences with data on markets for fishing services offered by charter and guide operations.[11] This approach uses actual market prices, possibly avoiding the aforementioned measurement problems, which could be important if we are interested in cardinal welfare measures. A leading case concerns resource allocation where there is a need for information on the relative marginal value in alternative uses.

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[10] For example, the commonly used trip count estimators imply an access value that is the reciprocal of the coefficient on the travel cost parameter (Haab and McConnell, 2002). The absolute value of the travel cost parameter, and therefore the calculated access value, will depend on the measurement of travel cost.

[11] The proposed approach is distinct from the hedonic travel cost model (Brown and Mendelsohn, 1984) that has been criticized for attempting to estimate a hedonic surface using non-market "prices" (Bockstael and McConnell, 1999) or the recent proposal to incorporate onsite costs into travel cost models within a hedonic framework (Landry and McConnell, 2007).

The hedonic strategy operates under two primary assumptions. First, each fishing site has an *intrinsic* set of harvest characteristics that are correctly perceived by anglers. This intrinsic set of harvest characteristics can be considered an exogenously given input representing variations in biomass, species distributions, and the incidence of regulations. Given the same level of technology and skill, a charter operating from a site with higher intrinsic harvest characteristics will yield larger harvest rates. Second, the hedonic strategy hypothesizes that the intrinsic harvest characteristics are reflected in charter prices at the county level.[12] For example, counties with higher intrinsic harvest rates will have higher charter fees on average. The hedonic approach values harvest attributes by identifying how charter fees vary with harvest characteristics across sites and observing where anglers choose to fish. With this information we hope to reveal, for example, that, all else equal, if an angler chooses a $500 trip in a county with a four fish intrinsic harvest rate, instead of a $475 trip from a county with a three fish intrinsic harvest rate, then they must be willing to pay at least $25 for a one fish increase in the intrinsic harvest rate.

Charter prices in our sample from the Gulf of Mexico are measured at the trip level, whereas the harvest attributes are measured at the county level. This suggests the use of a multilevel approach that explicitly models the random variation in charter fees across counties (Gelman, 2007). Such models have been applied in other hedonic studies where the attributes of interest are measured at higher levels of aggregation than prices (Beron, et al., 1999, Brown and Uyar, 2004, Goodman and Thibodeau, 2003, Kristofersson and Rickertsen, 2004, Kristofersson and Rickertsen, 2007). In general, our results suggest that the multilevel estimation approach

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[12] The county is selected as the level of aggregation based on the data available for the current application. Another level of aggregation could be used with the hedonic strategy.

provides more accurate estimates of standard errors and, therefore, more realistic bounds on implicit prices for harvest attributes in the model.

The next section introduces the hedonic theory of product differentiation as applied to the charter boat market. Section three presents the hedonic model specification and describes the estimation method. The next two sections describe the data and the results for the Gulf of Mexico application. The final section summarizes the paper and highlights the conclusions.

3.2. Hedonic Model

The purpose of this section is to adapt the hedonic theory of product differentiation and welfare measurement to markets for fishing charter services. We focus on the portions of the theory that enable us to measure the welfare effects of marginal changes in charter trip harvest attributes with limited data.[13] As an example, we will consider changes in intrinsic harvest rates.[14] The extension to other harvest attributes such as weight per fish and discard rates is straightforward. It is important to note that the choices over the number of trips to demand and supply are not explicitly modeled in what follows. Therefore, the proposed approach takes the number of trips as exogenous in the calculation of welfare measures.

Charter boats offer sportfishing trips that can differ in a variety of characteristics: duration, capacity, target species, expected harvest, etc. In most cases, a charter trip can be completely described by these characteristics. Anglers purchase the charter trips that satisfy their demand for trip characteristics. An angler will be *WTP* relatively more for a trip that offers a characteristic that they value highly. To the extent possible, charter boat operators will respond

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[13] Recent reviews of hedonic theory and applications to environmental and local public goods can be found in (Gyourko, et al., 1999, Palmquist, 2005, Taylor, 2003).

[14] The notion of intrinsic harvest characteristics is developed further below. For now, it is sufficient to note that intrinsic harvest characteristics are an exogenously given portion of expected trip quality.

by offering more trips with relatively valuable attributes. Therefore, following Rosen's (1974) model of product differentiation, the mix of charter trips offered and the trip prices reflect the interaction of buyers and sellers with respect to characteristics in the market.

In equilibrium, anglers have made their utility-maximizing charter trip choices, and the resulting charter prices just clear the market given the existing trip offerings and characteristics, and the prices of alternative trip configurations. Any differences in equilibrium trip prices can be explained in terms of differences in trip characteristics. The relationship between prices and characteristics defines a hedonic price function

$$p = h(\mathbf{z};\gamma) \tag{3.1}$$

where **z** is a vector of *m* trip characteristics and γ is a vector of parameters describing the shape of the hedonic function. The derivative of the hedonic function with respect to an attribute gives the implicit price of that attribute. It is reasonable to expect that the implicit prices will be non-constant because most attributes of charter boat trips cannot be costlessly repackaged in the short run. For example, it is unlikely that two half day trips are equivalent to one full day trip or that a single trip that harvests ten fish is the same as two trips that harvest five fish each.[15] Consequently, in most cases we would expect that the additional amount paid (implicit price) for increasingly high amounts of attributes, such as harvest rates, would decline as the total level of the attribute increases.

The problem for the charter boat firms is to maximize per trip profit, $\pi = h(\mathbf{z};\gamma) - c(\mathbf{z};\varphi)$, where $c(\cdot)$ describes the minimum cost of producing a trip with characteristics **z**, and φ is a vector characterizing individual producers. Note that there is a set of (short-run) trip attributes

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[15] Alternatively, repackaging may be costless, but arbitrage does not act in the charter market to equalize the total price of two half day trips with that of one full day trip or two five-fish harvest trips with one ten-fish harvest trip. Ekeland et al. (2004) demonstrate the implausible assumptions implicit in the structural model that implies a linear hedonic equation.

that are provided costlessly to the charter firm once they have set up their operation. These are either structural attributes fixed after the initial purchase, such as boat length and engine size, or exogenous attributes associated with location, marina, or environmental conditions. In the present case, the intrinsic harvest characteristics that are available from the charter boat county of origin are the exogenous attributes of interest.

The notion of intrinsic county-level harvest characteristics merits further discussion. We are interested in the portion of the county-level harvest characteristics that are given exogenously in the production process. As mentioned in the introduction, this intrinsic portion can be considered an exogenous input representing variations in biomass, species distributions, and the incidence of regulations. For example, the intrinsic harvest *rate* is increasing in biomass and decreasing in regulations. In this way, biomass and regulations form a lower and upper bound on the harvest rate, respectively, available from a given county. We assume that these bounds are summarized in the intrinsic harvest rate for *all species combined*.[16] A county can have a relatively low intrinsic harvest rate over all species if, for example, the species biomass available nearby is heavily regulated, even if the regulations are the same for all counties. Therefore, the county-level intrinsic harvest rate (and other harvest characteristics) will depend on the relative distribution of biomass and the incidence of regulations. Note that this conception of the intrinsic harvest rate summarizes the biologically determined "catch rate" and the endogenous "landings rate" common in models of angler behavior (Anderson, 1993, Woodward and Griffin, 2003).

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[16] We did not have sufficient data in our application to consider individual species separately. The extension to individual species is straightforward.

The minimum payment a charter firm requires to maintain a given profit level, π^0, for a charter trip with a given intrinsic harvest characteristic (e.g., keep rate), z_1, is described by the offer function

(3.2) $$o = o\left(z_1; \mathbf{z}_{-1}, \varphi, \pi^0\right)$$

where all other attributes are held constant at $\mathbf{z}_{-1}$. Since the intrinsic harvest characteristic is given exogenously, the offer price for this attribute depends only on the level of profit attainable. Therefore, the equilibrium price is determined entirely by demand once the intrinsic harvest characteristic has been established.

Given the hedonic price function, the angler's problem for any trip is to maximize the preference function, $u(x, \mathbf{z}; \phi)$, subject to a budget constraint, $y = h(\mathbf{z}; \gamma) + x$, where ϕ is a vector of preference function parameters and x is a composite commodity with a price normalized to unity. Note that this problem can also be represented as the choice over any one intrinsic harvest characteristic, say z_1, on the trip

(3.3) $$u\left(z_1, y^0 - b; \mathbf{z}_{-1}, \phi\right) = u^0$$

where b is the bid for charter trips that only vary in z_1, holding utility, income, and all other attributes constant at u^0, y^0, and $\mathbf{z}_{-1}$, respectively. The bid b implicitly measures the angler's *WTP* in terms of the income (or expenditures on other goods) necessary to maintain a constant utility level as the harvest characteristic changes. Inverting expression (3.3), the bid function is obtained as

(3.4) $$b = b\left(z_1; \mathbf{z}_{-1}, y^0, \phi, u^0\right)$$

to explicitly show the angler's *WTP* as a function of the harvest characteristic, holding income, utility, and all other characteristics constant. Note that, in this formulation, the bid function defines an indifference curve between the harvest characteristic and expenditure on other goods.

The derivative of the bid function with respect to z_1 gives the inverse compensated demand function for the harvest rate. This is useful for characterizing the first order conditions for the solution to the angler's problem

$$\frac{\partial u / \partial z_i}{\partial u / \partial x} = \frac{\partial h}{\partial z_i} = \frac{\partial b}{\partial z_i} \qquad i = 1, \ldots, m \tag{3.5}$$

where the bid function is evaluated at the highest level of utility obtainable. Equation (3.5) indicates that the optimal choice of harvest rate occurs where the implicit price of a change in the harvest rate equals the angler's marginal *WTP* (*MWTP*) on any given trip. Note that, in general, expression (3.5) does not suggest that the derivative of the hedonic price function with respect to an attribute is a *MWTP function* for changes in that attribute (McConnell and Phipps, 1987). Only at the chosen level of z_1 does the derivative of the hedonic function equal the angler's *MWTP*. At this point, it measures the additional money that the angler with a specific set of income, preferences, and characteristics would pay to purchase a charter trip with a (one unit) higher of the attribute. Other anglers with a different set of income, preferences, and characteristics would have a different equilibrium point on the hedonic schedule. Bayer et al. (2007) show that the average estimated implicit price will approximate the mean *MWTP* when the attribute varies more or less continuously throughout the market.[17] Therefore, in the present case, the mean *MWTP* for characteristic *i* is approximated by

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[17] In general, equilibrium implicit prices will exactly reflect mean preferences only when anglers are homogeneous. With heterogeneous anglers, the equilibrium implicit price for a specific attribute level reflects the *MWTP* of individuals on the margin between locations defining the change in attribute level. To demonstrate, we adapt the simple example in Bayer et al. (2007) to

(3.6) $$\overline{MWTP_i} \approx N^{-1}\sum_{n=1}^{N}\frac{\partial \hat{h}\left(\overline{\mathbf{z}}_n\right)}{\partial z_{i,n}} \approx \sum_{j=1}^{J}\pi_j\frac{\partial \hat{h}\left(\overline{\mathbf{z}}_j\right)}{\partial z_{i,j}}.$$

where N is the total number of trips and π_j is the proportion of total trips taken to county $j = 1, 2, \ldots, J$. Note that the expression in the second summation arises because harvest characteristics measured at the county level imply that each angler on every trip to the same county will be at the same margin and have the same *MWTP*.

The value of discrete changes in harvest characteristics cannot be measured without information about the marginal bid (inverse demand) function. This requires additional assumptions about the charter market and/or information about angler characteristics and preferences (Bockstael and McConnell, 2007).

3.3. Specification and Estimation

Theory does not offer guidance on the specification of the hedonic price function. Rather, the form of the price function is generally determined with an understanding of the market and measures of equation fit. We assume that offshore charter trips in the Gulf of Mexico are all offered in the same market and we attempt to identify the effects of cross-county variations in intrinsic harvest characteristics on the equilibrium market price. Variations across counties, instead of trips or vessels, are examined for two reasons. First, charter fee and harvest

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the chart boat market. Take, for example, charter trips that can reasonably offer the harvest of a specific species. If the species were available in only a few counties, then the hedonic price would reflect the *MWTP* of an angler with a relatively strong taste for the species. In this case, the mean *MWTP* is less than the implicit price because the majority of anglers are not *WTP* the equilibrium hedonic price. If we now consider a more continuous attribute, such as the harvest rate, then there are several margins. The margins correspond with difference in each pair of counties ranked according to harvest rate. If there are roughly an equal number of charter trips to each county, then averaging the equilibrium implicit price over all anglers in the sample approximates the mean *MWTP* of all anglers.

information was not available in our study area for the same set of trips; i.e., one dataset of trips had information on fees and another had information about harvests. Second, even if harvest data for each trip was available, this would represent the *ex post* quality of the trip and not the expected quality that clients and captains consider when negotiating a price. There are many ways to characterize the expected quality of a trip using harvest data (Freeman, 1995). As described in the previous section, we hypothesize that the exogenous portion of expected trip quality is indexed by the county-level intrinsic harvest characteristics. We proxy the intrinsic harvest characteristics with ten year averages for weight per fish, keep per unit effort, and discard per unit effort in each county.[18] Other key charter trip attributes in the hedonic function include the duration of the trip and the number of passengers.[19]

Multilevel specification and estimation is pursued because of the known power issues associated with models that have variables measured at different levels of aggregation. Specifically, OLS standard errors have been shown to be biased downwards when observations are correlated within each group or, in our case, county (Moulton, 1990). The hedonic price function for the Gulf of Mexico charter market is specified as variations on the following multilevel model (MLM)

$$p_{i,j} = \alpha_j + \beta_1 t_{i,j} + \beta_2 g_{i,j} + \varepsilon_{i.j} \tag{3.7}$$

where p_{ij}, t_{ij}, and g_{ij} are the price, trip hours, and number of passengers, respectively, for charter trip i taken in county j, α_j is a random intercept that measures the variation in fees across

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[18] In the hedonic approach, the link between the exogenous intrinsic harvest characteristics and equilibrium charter trip prices is of interest. Therefore, we model the intrinsic harvest characteristics directly rather than as arguments of a function for expected harvest quality per trip (McConnell, et al., 1995)

[19] Trip duration and number of passengers explain nearly seventy percent of the variation in charter fees. Other key attributes such as boat length and hours fished were omitted due to high correlation with duration and passengers. Data on more specific charter boat or trip features (e.g., air conditioning) was not available in our dataset.

counties and $\varepsilon_{ij} \sim iid\ N(0, \sigma_0^2)$.[20] Three different specifications are examined for the county level variation

(3.8)a $$\alpha_j = \alpha_0 + \alpha_1 w_j + \alpha_2 k_j + \alpha_3 d_j + \nu_j$$

(3.8)b $$\alpha_j = \alpha_0 + \alpha_1 w_j + \alpha_2 k_j + \alpha_3 d_j + \alpha_4 k_j^2 + \nu_j$$

(3.8)c $$\alpha_j = \alpha_0 + \alpha_5 \ln w_j + \alpha_6 \ln k_j + \alpha_7 \ln d_j + \nu_j$$

where w_j is the average weight per fish, k_j the average keep per unit effort, and d_j average discard per unit effort in each county and $\nu_j \sim iid\ N(0, \sigma_1^2)$. The level two county area error ν_j is assumed to be independent of the level one error, ε_{ij}, and the explanatory variables. Note that the measure of effort is angler hours fished per trip. The three specifications can be rewritten by inserting the level two models into the level one equation:

(3.7)a $$p_{i,j} = \alpha_0 + \alpha_1 w_j + \alpha_2 k_j + \alpha_3 d_j + \beta_1 t_{i,j} + \beta_2 g_{i,j} + \left\{ \nu_j + \varepsilon_{i.j} \right\}$$

(3.7)b $$p_{i,j} = \alpha_0 + \alpha_1 w_j + \alpha_2 k_j + \alpha_3 d_j + \alpha_4 k_j^2 + \beta_1 t_{i,j} + \beta_2 g_{i,j} + \left\{ \nu_j + \varepsilon_{i.j} \right\}$$

(3.7)c $$p_{i,j} = \alpha_0 + \alpha_5 \ln w_j + \alpha_6 \ln k_j + \alpha_7 \ln d_j + \beta_1 t_{i,j} + \beta_2 g_{i,j} + \left\{ \nu_j + \varepsilon_{i.j} \right\}.$$

These forms of the model highlight the separate variance components and the implied heteroskedasticity over county areas. The models are estimated via restricted maximum likelihood using the MIXED procedure in SAS.[21] An additional null model is estimated to formally examine the county-level variation in charter fees and to calculate the raw variance

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[20] Other multilevel specifications were considered; most notably, those that allowed the parameter on trip length to vary randomly across counties. However, the data did not support the estimation of these more complex specifications. Specifications that included simple interactions between the harvest variables and trip length were also unsuccessful at fitting the data.

[21] See the Appendix in Kristofersson and Rickertsen (2007) for an outline of the MIXED procedure in SAS as applied to the estimation of hedonic price equations. Singer (1998) also provides a detailed discussion on using the MIXED procedure to estimate of multilevel models.

partition coefficient (VPC). The VPC measures the proportion of the total variance in charter fees that occurs among counties as $\rho = \sigma_1^2/(\sigma_0^2 + \sigma_1^2)$.[22]

The average equilibrium implicit price and *MWTP* approximations for a change in key harvest attributes with the three specifications are given in Table 3 where A_j denotes the average angler hours fished per trip in county *j*. These formulae correspond with expression (3.6). Note that the measurements in kilograms are scaled to pounds by dividing by 2.2.

3.4. Data

The data for the estimation of the hedonic model of harvest value in the charter boat market comes from three sources, all of which are affiliated with the Marine Recreational Fisheries Statistics Survey (MRFSS). In all cases we selected sub-samples to correspond with single day, charter trips, fishing offshore (i.e., not inland).

Information on charter fees was obtained from an add-on to the weekly MRFSS For-Hire telephone survey conducted from 07/01/02 to 06/30/03.[23] In this add-on, charter captains were randomly selected from a master registry of 700 vessels to answer questions about trips taken in the week prior to the call. Captains were asked about the number and general characteristics of the trips they took in the prior week and were asked to report cost and price information for one of the trips. There was no information collected about the catch on any of these trips.[24] We began with a sub-sample of single day, offshore trips that either bottom fished or fished via trolling, casting, or drifting. One large vessel (>80ft.) with 10 trips, 3 of which had cost and price

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[22] The VPC is also equal to the intra-class correlation coefficient in the linear model without interactions and measures within county dependency.

[23] See Preliminary Results from the 2002/3 Gulf of Mexico Charter Boat Economic Survey (FHS Add-on) for Amendment 27/14 to the Reef and Shrimp FMPs, DRAFT 2/28/2007.

[24] There may have been catch information collected in the MRFSS intercept survey for the same trips reported by the captains in the for-hire telephone survey. However, there is no clear way to identify and link these records.

information, and one vessel with one low fee trip ($50) were removed. The final sample consisted of 356 vessels taking a total of 1,935 fishing trips, 584 of which had corresponding cost and price information. Note that trips were not reported from every county along the Gulf of Mexico and that we have assigned observations in counties with fewer than three reported trips to adjacent counties. This reduced the number of county areas from 28 to 23. Table 4 shows the average charter fee excluding tips (p), passengers (g), and boat hours (t) per trip for each sampled county area in the Gulf of Mexico.[25] The number of sample observations in each county is also shown in the table.

Estimates of the average keep per unit effort (k), discards per unit effort (d), and weight per fish (w) across all species are calculated from the MRFSS intercept survey data for each county area in the Gulf of Mexico. The average is over all species because we are unable to separately identify the effects of individual species or groupings on charter fees with a reasonable degree of statistical confidence. The effect of the red snapper harvest rate could be identified, but it was highly correlated with the overall harvest rate because red snapper is such a popular species.[26]

To be consistent with the MRFSS economic add-on sample, only single day charter trips fishing offshore with hook and line are included in the sample. There were 13,025 such trips sampled in the ten years prior to the MRFSS economic add-on survey (1992-2001). The data for the 109,989 fish measured on these trips were used to calculate the average weight per fish. The k and d across all species are calculated for each charter trip intercepted as the total observed harvest in numbers of fish (MRFSS Type A) and reported live discards in numbers of fish

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[25] The identity of the counties has been obscured to protect the privacy of operators in counties with a low number of charter operators.

[26] Correlation matrices are available upon request for keep and discard rates for the top recreational species in the Gulf of Mexico.

(MRFSS Type B2), respectively, divided by angler hours (*A*) given as the product of the hours fished on the trip and the number of fishing party members.[27] The variables *k*, *d*, and *A* are averaged over all trips and *w* is averaged over all fish for each county area in the Gulf of Mexico from 1992-2001 as shown in Table 5.

An estimate of the population proportion of the offshore charter trips originating in each county was generated as an annual average of trips observed in the MRFSS intercept survey. The estimated county shares from 2000 to 2006 are shown in Table 6 along with the annual average for each county (π_j) over the period that was used in the calculation of the mean *MWTP* in Table 3. The MRFSS intercept averages of *k*, *d*, and *w* were merged with the economic add-on survey by county area. The summary statistics for all model variables over the final combined sample are shown in Table 7.

3.5. Results

The parameter estimates for the seven estimated models are shown in Table 8. Measures of model fit are also presented, including negative two times the log-likelihood (-2 *LL*), the adjusted Akaike Information Criterion (*AICC*), and the coefficient of determination (R^2). Note that the R^2 for the OLS models is adjusted for the number of variables in the model and the R^2 for the multilevel models is measured as the proportional reduction in errors of prediction when the model is compared with the null model (Kreft and de Leeuw, 1998). Standard tests reject the normality of the level one (trip) residuals, but fail to reject the normality of the level two (county) residuals for all of the MLM specifications (except the null model).[28] Closer examination of the level one residuals suggests that the departure from normality is due to excess

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[27] Reported dead discards (MRFSS Type B1) are not considered in this analysis.

[28] Results for the Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling and Chi-square normality tests are available upon request.

kurtosis. However, this is not an issue because the primary interest is in the estimation of parameters on the county-level harvest variables.

OLS estimates of the parameters for the three specifications are shown in the first three columns of Table 8. Based on the adjusted R^2 measure, these models have a similar fit with the exogenous variables explaining nearly seventy percent of the variation in charter fees. The estimates of means and standard errors of the parameters on *g* and *t* are also similar across the OLS models as are the estimates of the model variance, σ_0^2. The primary difference among the specifications occurs among estimates for the county level harvest characteristics.

The MLM estimates for the three model specifications are shown in the last three columns of Table 8 and the fourth column shows the results for the estimation of the null MLM. Recall that the VPC estimated from the null model indicates the proportion of variation in charter fees that occurs across counties. In this case, more than 30 percent of the (explainable) variation in charter fees occurs across counties. Figure 1 shows the mean and spread (at the 0.05 level) of charter fees estimated for each county based on the random intercepts. This is the variation that we hope to explain with variations in harvest characteristics across counties.

The relatively high degree of clustering of charter fees within counties suggests that OLS will underestimate the standard errors on the county-level harvest characteristics. Indeed, the standard errors of the county-level harvest parameter estimates in the first three columns are smaller than the corresponding estimates in columns five through six. This indicates that, if the assumptions of the MLM are correct, the OLS estimates will be more likely to reject tests about parameter values and suggest confidence intervals that are too narrow.[29] For example, the OLS

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[29] Additionally, the degrees of freedom in the MLM significance tests for the harvest characteristics are more conservatively based on the number of county areas, rather than the total number of observations.

estimates incorrectly reject the hypothesis that the parameters on the weight variables (α_1 and α_5) are equal to zero at the 0.05 level.

The mean implicit prices and mean *MWTP* of the variables that enter the model linearly are simply the corresponding coefficient estimates. For example, looking at the MLM results for the logarithmic model, charter firms charge \$75.92(±\$7.3) on average for each additional trip hour and \$53.57(±\$6.9) extra on average for an additional passenger.[30] Note that, as described above, OLS underestimates the standard errors of the county (level two) harvest variables. Consequently, the OLS bounds are too narrow relative to the more accurate bounds estimated with the MLM models. For example, the confidence interval for MLM estimates of the parameter on weight, *w*, contains zero and negative values, whereas the bounds on the OLS estimates are everywhere positive.

The marginal values of the harvest characteristics are the primary interest of this study. Table 9 shows the calculation of the mean *MWTP* approximations from Table 3 using the MLM estimates over the three specifications. The upper and lower bounds of the estimates are shown based on a 95 percent confidence interval.

Results presented in Table 9 indicate that the means and bounds of the estimates vary somewhat depending on the specification. In particular, there is a noticeable difference between the calculations based on a single parameter estimate and those that are multiplied by a weighted factor. This occurs because the data were not weighted in the regressions.[31] The formulae in

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[30] The numbers in parenthesis are confidence intervals based on a 0.05 significance level. The validity of these and other calculated bounds on the model parameters depend on the validity of the normality assumption. We have already noted that the hypothesis of normality was rejected for the (trip) level one residuals. More robust nonparametric confidence intervals can be calculated using bootstrap (Wang, et al., 2006) or MCMC methods (Maindonald, 2007).

[31] The parameter estimates of the regressions will be unbiased without weighting as long as the weights are uncorrelated with the independent variables. Results based on the Hausman-type test

Table 3 suggest that the estimates in the first three rows are most likely to demonstrate this difference. For example, the mean *MWTP* to catch and keep an extra fish during each angler hour fished when calculated with the linear specification ($64.72) is considerably lower than the estimate with the logarithmic ($115.43) and quadratic ($120.72) models. A similar discrepancy occurs among the estimates of the mean *MWTP* to discard one less fish per angler hour. However, in this case, the linear ($25.52) and quadratic ($19.69) estimates are similar and both are different than the estimate from the logarithmic ($59.60) model. Again, referring to Table 3, the linear and quadratic calculations are based on the parameter estimate alone, whereas the logarithmic calculation involves a weighted factor. These discrepancies carry over to the other calculations in the table that are constructed using similar parameter combinations. In all cases, however, the calculations involving the weighted factors provide wider bounds on the estimates than those based solely on one parameter. Furthermore, the estimates with weighted factors include the county proportions that are consistent with the distribution of trips across counties in the population. This suggests that the calculations involving the weighted factors are likely to be more accurate measures of population mean *MWTP*. Therefore, we will concentrate on the estimates mean *MWTP* from the logarithmic specification.

Focusing on the estimates for the logarithmic MLM, anglers are *WTP* $26.89 on average to increase the expected (average) weight per fish kept on a trip by one pound. However, the confidence bounds on this estimate are quite wide, suggesting a marginal value of anywhere between -$4.40 and $58.19. The bounds on the keep rate are tighter, but still cover a wide range of values. On average, an angler is *WTP* $115.43 more per trip to increase the expected (average) number of fish kept per hour per angler by one. This translates to a *WTP* of $5.86 for

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presented in DuMouchel and Duncan (1983) suggests that this is a valid assumption with respect to the harvest variables.

an additional fish kept per trip. The estimate is on the lower end of the *WTP* per fish reported from the sample of studies analyzed by Johnston et al. (2006).[32]

The MLM-logarithmic model results for the discard rates suggest that, on average, anglers would be *WTP* \$2.90 to avoid throwing back an additional fish per trip. Interestingly, the marginal value of keep and discards is not symmetrical with anglers *WTP* more to keep a fish than they are *WTP* to avoid throwing one back. Again, though, the 95 percent confidence interval of the discard rate marginal value is wide, including both positive and negative values.

As shown in Table 3 and reported in Table 9, the mean *MWTP* per pound of fish kept per trip is calculated two ways. The first way assumes that the one pound increase is achieved via one more fish kept at the average weight. Using the MLM estimates for the logarithmic model, this approach gives a mean *MWTP* per pound of \$1.11. The second way assumes that the one pound increase is achieved via heavier fish, effectively increasing the weight of each of the average keep per trip. Using the MLM estimates of the logarithmic model, this approach gives a mean *MWTP* per pound of \$1.56. The ninety-five percent confidence interval calculated with the second method contains the interval calculated with the first approach. Note from Table 3, the two calculations in the logarithmic specification involve two different parameters (α_6 and α_5), but the same scaling factor. Therefore, a test of the difference in these parameters is a test of whether the two approaches of calculating the mean *MWTP* per pound per trip produce statistically different results. A t-test (df=19) of the hypothesis that $\alpha_6 - \alpha_5 = 0$ cannot be rejected with any reasonable degree of confidence (p= 0.6683) suggesting that, in effect, "a pound is a pound," regardless of how it is obtained.

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[32] The Johnston et al. estimates are also denominated in (June) 2003 dollars.

3.6. Summary and Conclusions

This paper introduced a novel approach to valuing recreational fishing harvest using data from markets for sportfishing services. The approach uses the hedonic theory of product differentiation to model the variation in charter trip fees associated with variations in trip and harvest attributes across locations. Expressions for calculating the mean *MWTP* of harvest attributes were presented that are derived directly from variations in charter market fees.

The hedonic approach was applied to estimate the marginal value of fish kept, fish discarded, and the average weight per fish in the market for offshore charter fishing in the Gulf of Mexico. Three alternative specifications of the hedonic function were estimated using OLS and multilevel modeling (MLM) techniques. The MLM estimators were examined because the harvest attributes were measured at a higher level of aggregation (county) than the prices and trip attributes.

Preliminary testing found that charter fees were clustered within counties in the Gulf of Mexico and that a significant portion of the explainable variation in fees occurred across counties. This fact lead to OLS standard errors on the county-level harvest characteristics that were smaller than those estimated via MLM techniques. This finding was consistent across hedonic specifications.

The average *MWTP* was calculated for changes in the average weight per fish kept and the number of fish kept and discarded per angler hour fished and per trip. The estimates were within the range of values estimated in other research. Point estimates suggested that the anglers are *WTP* more to keep an extra fish than then they are to avoid throwing one back. We also found that, for preferred model specification, the *MWTP* for an additional pound of fish is the same whether achieved via more fish or via heavier fish.

In using actual market prices, the hedonic approach can provide cardinal measures of *MWTP* that are free of the measurement problems that trouble methods such as travel cost models that use proxy prices. Cardinal measures of *MWTP* may be important, for example, when evaluating the efficiency of resource allocations among competing uses. It is important to note, however, the key assumptions that underlie the valuation estimates derived from the hedonic model. Specifically, we are assuming that the market for charter services is in a perfectly competitive equilibrium and that variations in (county-level) intrinsic harvest characteristics are reflected in the distribution of charter fees. For this to happen, the spatial distribution of the harvest characteristics needs to be understood by both firms and anglers and spatial arbitrage cannot act to equalize prices across the market.[33] We also hypothesized that the variations in the intrinsic harvest characteristics are exogenous to the firm's supply of charter services and reflect the distribution of species, biomass, and the incidence of regulations.

Assumptions were also made in the empirical application of the hedonic model. However, most of these assumptions, such those relating to the functional form and error distributions, are typical in applied valuation research. Of particular importance, though, is the assumption that the intrinsic harvest characteristics are uncorrelated with any of the unobservable components that determine charter fees. Also note the mean *MWTP* was assumed to be approximated by the weighted average implicit prices for each harvest attribute and that mean anglers per trip, hours fished per trip, and weight per fish were fixed in these calculations.

In closing note that, as with all hedonic valuation methods, information about preferences beyond *MWTP* is not forthcoming without further assumptions or data (Palmquist, 2005). Such information is necessary to evaluate the welfare effects of discrete changes in harvest

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[33] Ecosystem services, such as intrinsic harvest characteristics, are not spatially fungible; therefore, the benefits of these services are spatially explicit (Boyd and Banzhaf, 2007).

characteristics. The application of methods designed to identify or bound the value of discrete changes to the hedonic charter model is left for future research.

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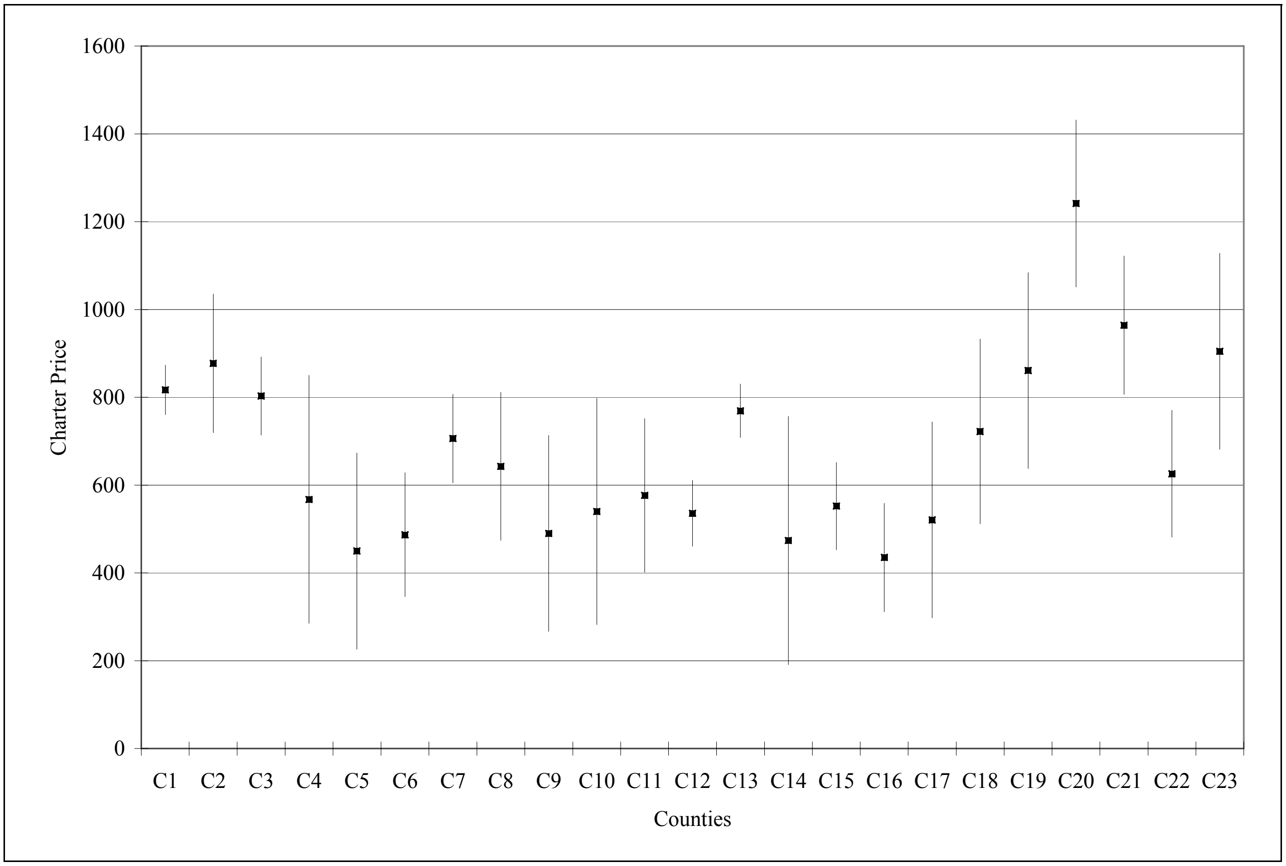

Figure 1. Estimated Variation in Mean Charter Fee per County

Table 3. Mean *MWTP* Approximations

Measure	Specification		
	Linear	Logarithmic	Quadratic
Mean *MWTP* per keep per angler hour fished (*$/fish/hour*)	α_2	$\alpha_6\sum_{j=1}^{J}\frac{\pi_j}{k_j}$	$\alpha_2+\alpha_4\sum_{j=1}^{J}\pi_j k_j$
Mean *MWTP* per discard per angler hour fished (*$/fish/hour*)	α_3	$\alpha_7\sum_{j=1}^{J}\frac{\pi_j}{d_j}$	α_3
Mean *MWTP* for an extra pound per fish kept (*$/lb/fish*)	$\alpha_1/2.2$	$\frac{\alpha_5}{2.2}\sum_{j=1}^{J}\frac{\pi_j}{w_j}$	$\alpha_1/2.2$
Mean *MWTP* per keep per trip (*$/fish/trip*)	$\alpha_2\sum_{j=1}^{J}\frac{\pi_j}{A_j}$	$\alpha_6\sum_{j=1}^{J}\frac{\pi_j}{k_j A_j}$	$\alpha_2\sum_{j=1}^{J}\frac{\pi_j}{A_j}$ $+.5\alpha_4\sum_{j=1}^{J}\frac{\pi_j k_j}{A_j}$
Mean *MWTP* per discard per trip (*$/fish/trip*)	$\alpha_3\sum_{j=1}^{J}\frac{\pi_j}{A_j}$	$\alpha_7\sum_{j=1}^{J}\frac{\pi_j}{d_j A_j}$	$\alpha_3\sum_{j=1}^{J}\frac{\pi_j}{A_j}$
Mean *MWTP* per pound per trip (achieved via one more keep) (*$/lb/trip*)	$\frac{\alpha_2}{2.2}\sum_{j=1}^{J}\frac{\pi_j}{A_j w_j}$	$\frac{\alpha_6}{2.2}\sum_{j=1}^{J}\frac{\pi_j}{k_j A_j w_j}$	$\frac{\alpha_2}{2.2}\sum_{j=1}^{J}\frac{\pi_j}{A_j w_j}$ $+\frac{.5\alpha_4}{2.2}\sum_{j=1}^{J}\frac{\pi_j k_j}{A_j w_j}$
Mean *MWTP* per pound per trip (achieved via heavier fish) (*$/lb/trip*)	$\frac{\alpha_1}{2.2}\sum_{j=1}^{J}\frac{\pi_j}{k_j A_j}$	$\frac{\alpha_5}{2.2}\sum_{j=1}^{J}\frac{\pi_j}{k_j A_j w_j}$	$\frac{\alpha_1}{2.2}\sum_{j=1}^{J}\frac{\pi_j}{k_j A_j}$

Notes: The variables k_j, d_j, and A_j measure, respectively, the mean keep per angler hour fished, mean discards per angler hour fished, and mean angler hours fished per trip from each county j. w is the average weight per fish in kilograms and π_j is the annual proportion of total trips from each county j.

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Table 4. 2002-03 For-Hire Economic Survey, County Averages for 584 charter trips

County	Obs.	*p*	*g*	*t*
C1	123	819.28	5.91	7.28
C2	14	907.14	5.57	9.57
C3	48	808.23	5.83	8.39
C4	3	491.67	5.00	8.17
C5	6	370.83	2.67	7.50
C6	18	465.00	4.11	6.25
C7	37	707.86	7.03	7.77
C8	12	636.67	4.00	8.13
C9	6	425.00	3.50	6.33
C10	4	468.75	3.75	7.50
C11	11	557.73	5.00	7.05
C12	68	531.69	3.31	6.56
C13	104	771.00	6.38	7.50
C14	3	333.33	3.00	6.50
C15	38	545.34	4.42	6.91
C16	24	414.29	3.75	5.63
C17	6	466.67	4.00	8.67
C18	7	735.71	5.57	9.93
C19	6	925.00	4.83	10.17
C20	9	1372.22	10.33	9.50
C21	14	1007.14	4.36	10.57
C22	17	619.71	4.06	8.12
C23	6	984.17	10.17	8.92

Notes: The sample size, Obs., in the per trip averages indicates the number of trips sampled. Variable *p* measures average charter fee per trip, *g* measures average number of passengers per trip, and *t* measures average boat hours per trip.

Table 5. Averages for charter trips intercepted by the MRFSS from 1992 to 2001

	per Trip				per Fish	
County	Obs.	*k*	*d*	*A*	Obs.	*w*
C1	1453	2.03	1.04	22.43	24409	1.53
C2	36	3.82	1.51	33.85	700	1.52
C3	722	1.35	0.39	24.10	8354	1.47
C4	11	1.23	1.72	24.00	125	0.95
C5	79	0.39	0.83	17.44	263	1.52
C6	167	0.71	2.26	15.47	753	1.48
C7	103	1.71	0.89	36.24	1614	1.59
C8	36	0.88	1.48	18.69	195	1.48
C9	48	0.92	1.76	20.82	92	1.34
C10	72	0.99	2.24	18.45	304	1.23
C11	46	0.71	0.79	22.23	452	1.40
C12	5388	0.55	0.37	18.56	20671	3.19
C13	2316	1.29	0.72	26.46	33638	1.96
C14	73	0.20	0.81	13.97	123	1.40
C15	829	1.01	1.09	18.31	7470	1.89
C16	148	0.74	2.01	17.17	1048	1.97
C17	54	0.89	1.36	21.92	477	1.06
C18	28	1.66	1.32	25.68	330	2.70
C19	60	1.33	0.53	25.13	328	2.45
C20	81	2.06	1.27	45.89	744	1.94
C21	256	1.32	0.58	23.79	1621	3.03
C22	204	2.16	1.01	23.75	1530	2.04
C23	815	0.93	0.49	32.11	4748	2.41

Notes: The variables *k*, *d*, and *A* measure, respectively, the mean keep per angler hour fished, mean discards per angler hour fished, and mean angler hours fished per trip. *w* measures the average weight per fish in kilograms. The sample size, Obs., in the per trip averages indicates the number of trips sampled, whereas the sample size, Obs., for per fish average weight indicates the number of fish sampled.

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Table 6. 2000-2006 Annual County Shares of Offshore Charter Trips (percentage by county)

County	2000	2001	2002	2003	2004	2005	2006	π_j
C1	9.1	9.46	8.58	6.2	5.98	5.53	6.95	7.40
C2	0.1	0.21	0.16	0.39	0.35	0.2	0.38	0.26
C3	10.27	5.58	7.43	7.5	9.25	10.51	8.67	8.46
C4	0.07	0	0	0.08	0.04	0.1	0	0.04
C5	0.27	0.38	0.86	1.1	3.19	1.52	1.59	1.27
C6	0.9	0.54	0.86	2.35	2.28	3.03	0.83	1.54
C7	0.7	0.92	1.06	1.33	1.38	1.52	2.49	1.34
C8	0.27	0.08	0.08	1.02	0.79	0.88	1.34	0.64
C9	0.37	0.21	0.78	1.33	1.38	3.08	1.27	1.20
C10	0.47	0.38	0.41	0.35	0.63	0.2	0.25	0.38
C11	0.9	0.25	0.41	1.33	1.54	0.44	0.45	0.76
C12	42.37	47.46	45.06	43.01	30.4	35.94	33.21	39.63
C13	21.47	19.46	16.79	16.01	25.1	23.62	27.09	21.36
C14	0.37	0.54	0.49	0.98	0.47	0.64	0.7	0.60
C15	4.41	7.25	7.52	8.16	8.78	5.87	4.72	6.67
C16	0.7	0.58	2.04	2.79	1.81	1.76	0.25	1.42
C17	0.47	0.13	0.16	0.27	0.43	0.44	0.13	0.29
C18	0.47	0.38	0.33	1.1	1.1	0.88	0.89	0.74
C19	0.54	0.29	0.57	0.27	0.47	0.34	0.38	0.41
C20	0.03	0.04	0.16	0.35	0.63	0.39	5.35	0.99
C21	1.34	1.92	2.37	1.22	1.18	1.61	0.83	1.50
C22	0.3	0.42	1.55	1.18	1.3	0.49	0.96	0.89
C23	4.11	3.54	2.33	1.65	1.5	1.03	1.27	2.20
Total	100	100	100	100	100	100	100	100

Source: MRFSS intercept survey. π_j averages the annual proportions in each county observed between 2000 and 2006.

Table 7. Sample Summary Statistics for 584 charter trips

Variable	Mean	Std Dev	Minimum	Maximum
p	707.40	360.29	200.00	2300.00
g	5.34	2.77	1.00	20.00
t	7.52	2.52	2.00	15.50
w	1.91	0.57	0.95	3.19
k	1.39	0.65	0.20	3.82
d	0.94	0.47	0.37	2.26
$ln(k)$	0.21	0.50	-1.63	1.34
$ln(d)$	-0.18	0.50	-0.99	0.82
$ln(w)$	0.61	0.27	-0.05	1.16
A	23.67	5.76	13.97	45.89

Table 8. Parameter Estimates

	OLS			MLM			
Parameter	Linear	Logarithmic	Quadratic	Null	Linear	Logarithmic	Quadratic
α_0	-296.78**	-228.39**	-423.22**	676.68**	-368.57**	-273.44**	-427.46**
	(66)	(38.15)	(84.58)	(50.93)	(114.04)	(54.46)	(131.88)
$\beta_1 (t)$	73.52**	73.64**	73.86**		75.9**	75.92**	75.9**
	(3.69)	(3.67)	(3.68)		(3.71)	(3.7)	(3.71)
$\beta_2 (g)$	55.64**	54.06**	54.1**		53.93**	53.57**	53.6**
	(3.46)	(3.46)	(3.5)		(3.55)	(3.55)	(3.57)
$\alpha_1 (w)$	41.02**		59.3**		65.36		65.43
	(19.13)		(20.55)		(38.95)		(39.04)
$\alpha_2 (k)$	78.56**		187.93**		64.72**		140.3
	(15.24)		(48.47)		(26.74)		(88.8)
$\alpha_3 (d)$	-35.7*		-20.11		-25.52		-19.69
	(20.89)		(21.82)		(40.84)		(41.45)
$\alpha_4 (k^2)$			-27.70				-20.50
			11.96				21.86
$\alpha_5 (\ln w)$		101.71**				127.27	
		(41.25)				(75.57)	
$\alpha_6 (\ln k)$		116.27**				90.54**	
		(20.66)				(34.73)	
$\alpha_7 (\ln d)$		-34.19*				-31.32	
		(20.34)				(41.57)	
σ_0^2	43293**	43060**	42948**	103049**	39714**	39715**	39723**
	(2547)	(2533)	(2529)	(6160)	(2375)	(2374)	(2376)
σ_1^2				49435**	5690**	5019**	5727**
				(18546)	(2982)	(2704)	(3109)
ρ				0.32	0.13	0.11	0.13
-2 LL	7849	7844	7836	8436	7820	7817	7811
AICC	7851	7846	7838	8440	7824	7821	7815
R^2	0.6665	0.6683	0.6691		0.7022	0.7066	0.7019

Notes: Standard errors are shown in parentheses below the estimates. *Significant at the 0.10 level. **Significant at the 0.05 level. The R^2 is the adjusted measure for the OLS models and the proportional reduction in errors of prediction compared with the null model for the multilevel models (see text).

Table 9. Mean *MWTP* Approximations with MLM Estimates ($2002/03)

Measure	Specification		
	Linear	Logarithmic	Quadratic
Mean *MWTP* per keep per angler hour fished (*$/fish/hour*)	12.32	28.65	-12.96
	64.72	**115.43**	**120.72**
	117.12	202.20	254.40
Mean *MWTP* per discard per angler hour fished (*$/fish/hour*)	-105.56	-214.63	-100.94
	-25.52	**-59.60**	**-19.69**
	54.53	95.44	61.55
Mean *MWTP* for an extra pound per fish kept (*$/lb/fish*)	-4.98	-4.40	-5.03
	29.65	**26.89**	**29.68**
	64.28	58.19	64.39
Mean *MWTP* per keep per trip (*$/fish/trip*)	0.59	1.45	-1.14
	3.09	**5.86**	**6.25**
	5.59	10.27	13.64
Mean *MWTP* per discard per trip (*$/fish/trip*)	-5.03	-10.45	-4.81
	-1.22	**-2.90**	**-0.94**
	2.60	4.65	2.94
Mean *MWTP* per pound per trip (achieved via one more keep) (*$/lb/trip*)	0.12	0.28	0.88
	0.64	**1.11**	**1.70**
	1.15	1.95	2.52
Mean *MWTP* per pound per trip (achieved via heavier fish) (*$/lb/trip*)	-0.32	-0.26	-0.33
	1.92	**1.56**	**1.92**
	4.16	3.39	4.17

Notes: The bold numbers indicate average effects and the numbers above and below indicate lower and upper bounds based on a 95 percent confidence interval around mean estimate. The quadratic specification estimates involving *k* are combinations of two estimated parameters as shown in Table 3. Standard errors and the corresponding bounds for these estimates were generated considering the variation in both parameters.

4. Economic Allocation of Red Grouper

4.1. Introduction

In allocating the red grouper *TAC* between commercial and sport fishing sectors, the total economic value is maximized when the incremental value gained by a sector receiving a larger allocation is just equal to the incremental value lost in another sector due to a corresponding smaller allocation. The use of the equimarginal principle to determine the economically optimal allocation among commercial and recreational sectors requires information about how the allocated harvest generates value in these components of the fishery. In this chapter we use the models estimated in Chapters 2 and 3 to evaluate the effects of red grouper allocation policies on the commercial and recreational sectors in the Gulf of Mexico. We first consider the efficiency of the current allocation and then determine what can be said regarding the optimal allocation and the welfare effects of allocation changes.

4.2. Efficiency of the Current Allocation

Chapter 3 reported an average *MWTP* of \$1.11(±\$0.64) per pound (achieved via an extra fish) for the recreational sector.[34] Note that this measure was assumed to be the same for all species, including red grouper, and is a function of the county-weighted averages for keep per angler hour fished, angler hours fished, and average weight per fish. One way to tailor the estimate for mean *MWTP* per pound to the present case is to recalculate the average with "red-grouper" trips only. Given the existing data, this amounts to identifying trips in each county that kept or discarded red grouper and then averaging the *MWTP* per pound over these trips.

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[34] The values in parentheses indicate the 95 percent confidence interval around the point estimate of the mean *MWTP*. All dollar values in this chapter are denominated in 2003 dollars unless indicated otherwise.

Table 10 shows the annual proportion of trips in each county that either kept or discarded red grouper between 2000 and 2006. The average annual proportion over the seven years is shown in the last column. This average annual proportion can be used to re-scale the proportion of all trips originating from each county as follows

$$\pi_j^{RG} = \frac{\pi_j \kappa_j}{\sum_{j=1}^{J} \pi_j \kappa_j} \tag{4.1}$$

where κ_j is the average annual proportion of red grouper trips from county *j* and π_j is the average annual proportion of all trips originating from county *j* as defined in Chapter 3. The proportion, π_j^{RG} can be used in place of π_j in the formulas in Table 1 of Chapter 3 to calculate the mean *MWTP* values over red grouper trips.

Calculating the mean *MWTP* for an extra pound per fish in this way gives a value of $1.03(±$0.77) per pound if the increase is achieved via an extra fish.[35] This value is lower than the estimate over all fish because the angler hours fished and the keep per angler hour fished on these trips was higher, on average, for red grouper trips than for all trips.[36] In effect, the average keep per trip is higher on trips that kept or discarded red grouper suggesting that these trips are at a higher margin than other trips. The higher margin corresponds with a lower mean *MWTP*.[37] Note that this approach only averages the *MWTP* estimates over the trips that kept or discarded red grouper and, therefore, does not consider the values of other anglers who did not catch red grouper. Furthermore, the difference between the mean *MWTP* per pound for all fish and red

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[35] The mean *MWTP* per pound achieved via heavier fish on red grouper trips is $1.45(±$1.68). However, an empirical test reported in Chapter 2 indicated that the mean *MWTP* per pound achieved via an extra fish was not statistically different than the mean *MWTP* per pound achieved via heavier fish.

[36] The average weight per fish on trips that kept or discarded red grouper was slightly lower than the average over all trips.

[37] Note that the lower marginal value actual corresponds to a higher total value.

grouper derives from the difference in the overall keep per trip and the average weight per fish; not necessarily because of differences in species preferences. There was not enough information to identify anglers' species preferences using the model and data reported in Chapter 3.

The measure of mean *MWTP* per pound of red grouper calculated for the recreational sector will be close to the marginal value at the aggregate harvest in 2003 because this was the study year for the analysis. Note, however, that this value is per pound of whole fish and the allocation calculations are typically made in terms of gutted weight. The comparable mean *MWTP* per pound of gutted weight can be found by dividing the whole fish estimate by the poundage gutted weight from a pound of whole fish. According to the SEDAR 12 for Gulf of Mexico Red Grouper, there is 0.847 (1/1.18) pounds of gutted weight, on average, in every pound of red grouper harvested. Using this factor, the mean *MWTP* per pound of gutted weight in the recreational sector is $1.21(±$0.91).

Chapter 2 described the estimation of an aggregate commercial demand schedule for red grouper quota in the Gulf of Mexico. The schedule suggests that the commercial sector *MWTP* at the 2003 harvest of 4,937,970 pounds of gutted weight is approximately $1.14/lb. Interestingly, this is very close to the point estimate of the mean *MWTP* estimated for the recreational sector ($1.21/lb), suggesting that the current allocation may be efficient or, at least, not too far off. Note, however, that the 95 percent confidence interval of the recreational mean *MWTP* per pound of red grouper ranges from $0.26 to $1.80. Similar confidence intervals were not calculated for the marginal benefit estimates in the commercial sector.

Figure 2 further illustrates what we can learn about the efficiency of the existing allocation with information on the commercial *MWTP* schedule and a point estimate of the *MWTP* in the recreational sector. The figure depicts the allocation of quota across the horizontal axis and tracks the marginal value of quota to the commercial and recreational sectors on the left and right vertical axes, respectively. A downward sloping commercial demand for quota and one point on the recreational *MWTP* curve are shown at *E*. The starting allocation is marked at A^0 and the current *MWTP* in the commercial and recreational sectors are marked as $MWTPc^0$ and $MWTPr^0$, respectively. Using 2003 as the base year, the starting allocation of the 6,213,800 pounds landed is approximately 79% (4,937,970) commercial and 21% recreational (1,275,830).[38] For the sake of discussion, assume that the recreational mean *MWTP* and the commercial marginal benefit are at the point estimates reported above. In this case, $MWTPr^0$ = \$1.21 and $MWTPc^0$ = \$1.14 so that the *MWTP* per pound is higher for recreational fishing. This suggests that the extra benefits of a larger allocation to the recreational sector would be greater than the reduction in benefits to the commercial sector. However, without the complete *MWTP* schedule for the recreational sector we do not know how much to reallocate.

The location of the efficient allocation depends on the shape and the slope of the *MWTP* schedule for the recreational sector. A number of linear possibilities are shown in light shading around point E. The maximum that the commercial quota would have to be reduced is shown at A^{max}, corresponding with the case of a perfectly elastic recreational *MWTP* schedule. Based on the marginal value schedule calculated in Chapter 2, the commercial harvest level at $A^{\max}$ is the level demanded when the cost is \$1.21/lb or about 4.77 million pounds (MP). This suggests that the most that would be economically reallocated from the commercial to the recreational sector would be about 0.168 MP. Caution should be used, however, in interpreting this example because, again, the 95 percent confidence interval around the recreational mean *MWTP* per pound of red grouper contains the commercial estimate of *MWTP*.

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[38] There was no separate quota management for the red grouper fishery in 2003. Red grouper were considered part of the swallow water grouper quota.

4.3. Effects of Allocation Changes

The Gulf of Mexico Fishery Management Council is proposing a one percent change in the allocation of the red grouper TAC between the commercial and recreational sectors.[39] Various levels for the TAC are considered for the fishery. However, for illustration purposes, we will assume that the base TAC and allocation are given by the harvest levels observed in 2003. In this case, the hypothetical TAC would be 6,213,800 allocated 20.5 percent recreational and 79.5 percent commercial.[40] In what follows we examine the potential cost to the commercial sector and benefits to the recreational sector of a one percent change in this allocation in favor of the recreational sector.

The methods for calculating the welfare effects of discrete changes in the commercial quota for red grouper were described in Chapter 2. Essentially, the approach calculates the area under the marginal benefit schedule for quota between the base and proposed allocation levels. Calculated in this manner, the one percent reallocation reduces commercial landings from 4,937,970 to 4,875,832 pounds and costs the commercial sector $71,628.

The one percent reallocation to the recreational sector would increase landings from 1,275,830 to 1,337,968 pounds of gutted weight. Measuring the welfare effect of this 62,138 pound increase is difficult because the valuation model described in Chapter 3 only generated an estimate of one point along the marginal benefit schedule for the recreational sector. If we assume, however, that marginal benefit schedule for this sector is relatively flat in the area of a one percent change, then the value of this additional harvest to the recreational sector is simply

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[39] Draft Reef Fish Amendment 30B: Gag – End Overfishing and Set Management Thresholds and Targets, Red Grouper – Set Optimum Yield TAC and Management Measures, and Marine Reserves October 2007.

[40] For reference, the "no action" proposal by the Gulf of Mexico Fishery Management Council in Reef Fish Amendment 30B allocates 6,560,000 pounds of gutted red grouper as 23 percent recreational and 77 percent commercial.

the estimated mean *MWTP* times the change in harvest or $75,187(±$56,546) [62,138*$1.21(±$0.91)]. In any case, as shown by Freeman (1974), this type of calculation will yield an upper bound on the actual welfare effect. This assumption may not be appropriate for larger allocation changes. Potential approaches in the case of larger changes are discussed in the Appendix.

The cost of the one percent reallocation of the (2003) red grouper harvest in terms of foregone landings in the commercial sector can be compared with the benefit of the reallocation in terms of the value of additional landings in recreational sector. This comparison reveals that he benefits of the reallocation to the recreational sector**,** $75,187, are greater than the loss of benefits to the commercial sector, $71,628. In this case, the one percent reallocation may improve the efficiency of the red grouper resource use.

4.4. Reference

Freeman, A. M., III. "On Estimating Air Pollution Control Benefits from Land Value Studies." *Journal of Environmental Economics and Management* 1, no. 1(1974): 74-83.

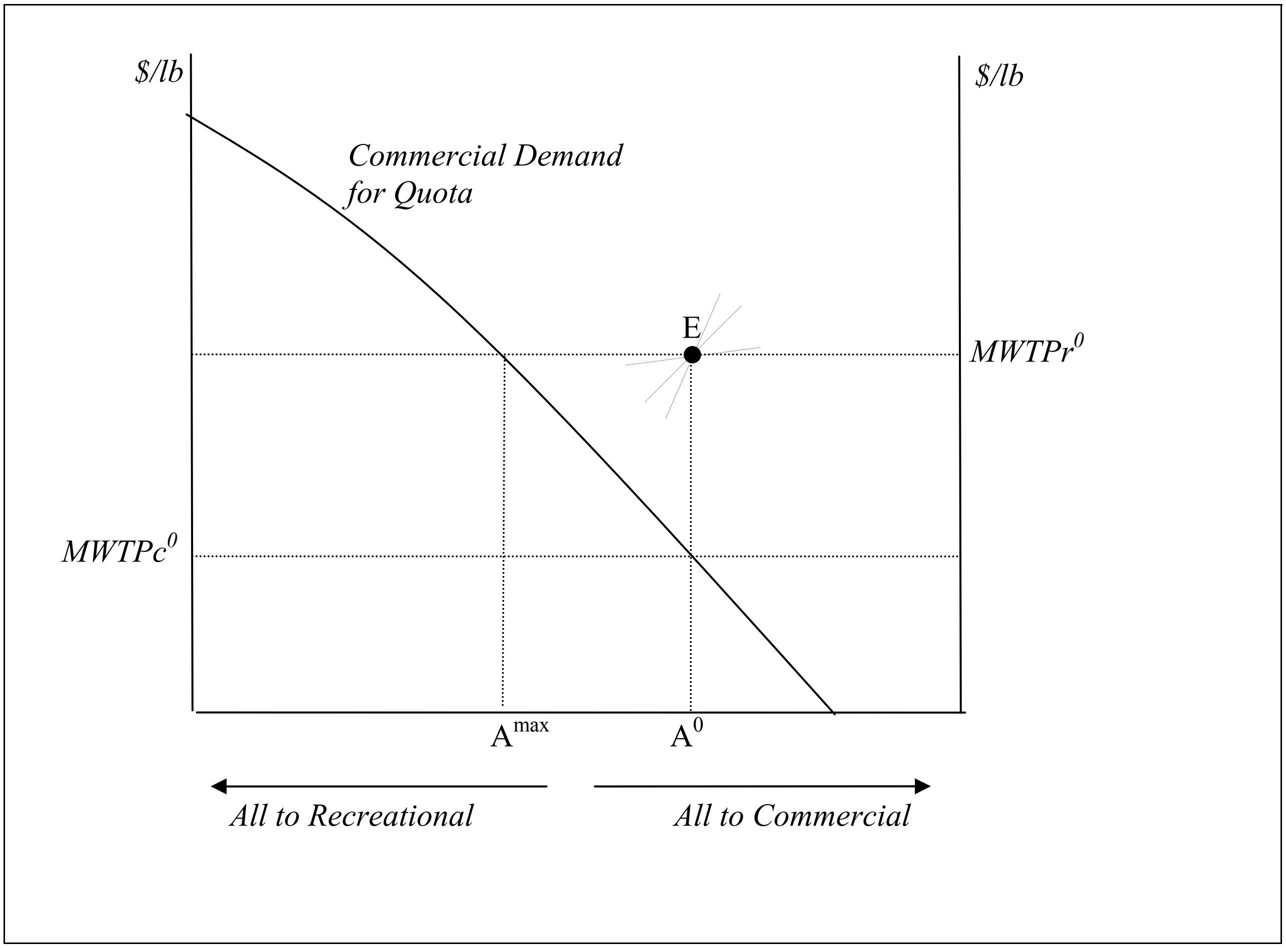

Figure 2. Efficiency of Current Allocation

Table 10. Proportion of Offshore Charter Trips Catching Red Grouper in the Gulf of Mexico by County

	2000	2001	2002	2003	2004	2005	2006	2000-2006 (κ_j)
C1	0.00	1.00	12.00	41.00	30.00	27.00	17.00	18.29
C2	0.00	0.00	0.00	30.00	44.00	25.00	0.00	14.14
C3	14.00	25.00	40.00	53.00	54.00	70.00	54.00	44.29
C4	50.00	0.00	0.00	0.00	100.00	100.00	0.00	35.71
C5	0.00	0.00	5.00	4.00	4.00	0.00	4.00	2.43
C6	37.00	62.00	33.00	47.00	55.00	42.00	31.00	43.86
C7	5.00	0.00	12.00	68.00	14.00	61.00	28.00	26.86
C8	38.00	50.00	100.00	85.00	90.00	56.00	76.00	70.71
C9	55.00	0.00	11.00	59.00	63.00	59.00	50.00	42.43
C10	29.00	11.00	50.00	0.00	44.00	25.00	50.00	29.86
C11	37.00	17.00	20.00	62.00	67.00	67.00	57.00	46.71
C12	2.00	4.00	5.00	7.00	6.00	4.00	4.00	4.57
C13	5.00	10.00	22.00	35.00	57.00	52.00	26.00	29.57
C14	9.00	15.00	8.00	12.00	50.00	31.00	0.00	17.86
C15	50.00	51.00	47.00	49.00	54.00	46.00	22.00	45.57
C16	52.00	43.00	38.00	37.00	50.00	56.00	0.00	39.43
C17	43.00	0.00	50.00	14.00	18.00	11.00	0.00	19.43
C18	64.00	100.00	75.00	61.00	43.00	50.00	86.00	68.43
C19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C23	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.29

Source: MRFSS Intercept Survey (Trips where Types A or B2 included red grouper)

Chapter 2

Appendix A: Vertical line model parameter estimates

Model Summary	
Model Variables	4
Parameters	166
Equations	4
Number of Statements	252

Note: The parameter beta12 is shared by 2 of the equations to be estimated.

Note: The parameter beta13 is shared by 2 of the equations to be estimated.

Note: The parameter beta14 is shared by 2 of the equations to be estimated.

Note: The parameter beta23 is shared by 2 of the equations to be estimated.

Note: The parameter beta24 is shared by 2 of the equations to be estimated.

Note: The parameter beta34 is shared by 2 of the equations to be estimated.

The 4 Equations to Estimate	
redgrplbs =	F(alpha1(esf_a2), beta11(esf_a1), beta12, beta13, beta14, a1, a2, a3, a4, a5, a6, a7, a8, a9, m2a, m3a, m4a, c1, d1, e1, z1, ban1, j1, m5a, m6a, m7a, m8a, m9a, m10a, m11a, m12a, g1, g2, g3, g4, y1, y2, gg1, gg2, gg3, gg4, mx1)
swgrplbs =	F(beta12, alpha2(esf_a2), beta22(esf_a1), beta23, beta24, a10, a11, a12, a13, a14, a15, a16, a17, a18, m2b, m3b, m4b, c2, d2, e2, z2, ban2, j2, m5b, m6b, m7b, m8b, m9b, m10b, g5, m11b, m12b, g6, g7, g8, y4, y5, gg5, gg6, gg7, gg8, mx2)
swsnaplbs =	F(beta13, beta23, alpha3(esf_a2), beta33(esf_a1), beta34, a19, a20, a21, a22, a23, a24, a25, a26, a27, m2c, m3c, m4c, c3, d3, e3, z3, ban3, j3, m5c, m6c, m7c, m8c, m9c, m10c, m11c, m12c, g9, g10, g11, g12, y7, y8, gg9, gg10, gg11, gg12, mx3)
l_misclbs =	F(beta14, beta24, beta34, alpha4(esf_a2), beta44(esf_a1), a28, a29, a30, a31, a32, a33, a34, a35, a36, m2d, m3d, m4d, c4, d4, e4, z4, ban4, j4, m5d, m6d, m7d, m8d, m9d, m10d, m11d, m12d, g13, g14, g15, g16, y10, y11, gg13, gg14, gg15, gg16, mx4)

Observations will be weighted by	inv

NOTE: At FIML Iteration 0 CONVERGE=0.001 Criteria Met.

Data Set Options	
DATA=	NEW9
OUT=	REST
OUTEST=	FIN

Minimization Summary	
Parameters Estimated	162
Method	Gauss
Hessian	GLS
Covariance Estimator	Cross
Iterations	0

Final Convergence Criteria	
R	6.329E-6
PPC(beta13)	0.002668
RPC	.
Object	.
Trace(S)	101941.4
Gradient norm	1.9E-12
Log likelihood	-567851

Observations Processed	
Read	19503
Solved	19503

Nonlinear FIML Summary of Residual Errors							
Equation	DF Model	DF Error	SSE	MSE	Root MSE	R-Square	Adj R-Sq
redgrplbs	40.5	19463	1.2102E8	6218.1	78.8551	0.4114	0.4102
swgrplbs	40.5	19463	2.8431E8	14608.2	120.9	0.3083	0.3069
swsnaplbs	40.5	19463	6.4459E8	33119.6	182.0	0.4064	0.4052
l_misclbs	40.5	19463	9.3824E8	48207.7	219.6	0.1179	0.1161

Nonlinear FIML Parameter Estimates				
Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
alpha1	0.032267	0.2718	0.12	0.9055
beta11	8.782671	13.6642	0.64	0.5204
beta12	13.48016	11.6015	1.16	0.2453
beta13	10.66284	7.1388	1.49	0.1353
beta14	-44.9748	5.5976	-8.03	<.0001
a1	-4.0068	5.6020	-0.72	0.4745
a2	7.301176	6.3110	1.16	0.2473
a3	87.13593	6.3681	13.68	<.0001
a4	88.12353	5.1820	17.01	<.0001
a5	67.91923	4.5512	14.92	<.0001
a6	90.43974	4.1565	21.76	<.0001
a7	57.71192	5.1873	11.13	<.0001
a8	39.29748	6.3834	6.16	<.0001
a9	12.1922	8.4243	1.45	0.1478
m2a	0.608317	3.6851	0.17	0.8689
m3a	-3.41422	3.6928	-0.92	0.3552

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
m4a	3.127027	3.1868	0.98	0.3265
c1	-6.21402	6.8019	-0.91	0.3610
d1	-55.1074	8.4502	-6.52	<.0001
e1	25.96188	2.3749	10.93	<.0001
z1	-0.01044	0.00965	-1.08	0.2792
ban1	4.428685	1.3623	3.25	0.0012
j1	-0.11024	0.2730	-0.40	0.6863
m5a	10.14146	3.0302	3.35	0.0008
m6a	13.92493	2.7952	4.98	<.0001
m7a	15.5874	2.7709	5.63	<.0001
m8a	13.98367	2.9478	4.74	<.0001
m9a	21.32203	4.3827	4.87	<.0001
m10a	14.85631	3.2037	4.64	<.0001
m11a	0.66091	3.4504	0.19	0.8481
m12a	2.528476	3.8279	0.66	0.5089
g1	-1.10329	5.5885	-0.20	0.8435
g2	47.77745	4.9521	9.65	<.0001
g3	12.83823	2.5854	4.97	<.0001
g4	0.615518	6.4639	0.10	0.9241
y1	11.38806	1.7495	6.51	<.0001
y2	-8.14415	1.9322	-4.21	<.0001
gg1	-7.99403	6.0729	-1.32	0.1881
gg2	27.80314	3.1431	8.85	<.0001
gg3	27.59864	4.1977	6.57	<.0001

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
gg4	26.98418	4.0499	6.66	<.0001
mx1	-5.57789	10.3823	-0.54	0.5911
alpha2	1.49472	0.5194	2.88	0.0040
beta22	103.2799	16.7141	6.18	<.0001
beta23	-117.977	9.8051	-12.03	<.0001
beta24	0.651032	7.7711	0.08	0.9332
a10	0.906151	12.1528	0.07	0.9406
a11	5.399202	14.8622	0.36	0.7164
a12	74.09588	16.0755	4.61	<.0001
a13	72.697	10.9347	6.65	<.0001
a14	95.72441	8.5872	11.15	<.0001
a15	78.89168	7.9428	9.93	<.0001
a16	114.0108	8.1542	13.98	<.0001
a17	42.90961	7.5234	5.70	<.0001
a18	-0.52496	8.8193	-0.06	0.9525
m2b	-12.7933	4.4790	-2.86	0.0043
m3b	-5.42027	3.5750	-1.52	0.1295
m4b	-28.7012	4.1922	-6.85	<.0001
c2	-38.2442	10.9852	-3.48	0.0005
d2	-117.044	15.5248	-7.54	<.0001
e2	55.21201	4.1775	13.22	<.0001
z2	0.017206	0.0117	1.46	0.1431
ban2	-2.89938	2.3766	-1.22	0.2225
j2	-0.58222	0.5102	-1.14	0.2538

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
m5b	-27.9365	4.4540	-6.27	<.0001
m6b	-46.223	4.8282	-9.57	<.0001
m7b	-71.2561	5.2086	-13.68	<.0001
m8b	-84.1051	6.1985	-13.57	<.0001
m9b	-61.9243	9.9682	-6.21	<.0001
m10b	-13.3685	4.3703	-3.06	0.0022
g5	9.343434	6.1660	1.52	0.1297
m11b	-42.3064	4.3637	-9.70	<.0001
m12b	-15.6644	4.6312	-3.38	0.0007
g6	45.13755	8.1801	5.52	<.0001
g7	28.20156	5.6814	4.96	<.0001
g8	65.03702	8.3144	7.82	<.0001
y4	6.143341	2.9168	2.11	0.0352
y5	-7.14369	3.1393	-2.28	0.0229
gg5	120.4778	6.1868	19.47	<.0001
gg6	-4.23832	10.5756	-0.40	0.6886
gg7	55.2323	5.5932	9.87	<.0001
gg8	5.991257	10.9620	0.55	0.5847
mx2	24.63797	15.5151	1.59	0.1123
alpha3	-0.43082	0.9030	-0.48	0.6333
beta33	171.7643	23.4483	7.33	<.0001
beta34	-45.0124	8.9205	-5.05	<.0001
a19	-13.5455	6.7729	-2.00	0.0455
a20	-13.9482	9.1016	-1.53	0.1254

Nonlinear FIML Parameter Estimates

Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
a21	-35.23	50.7303	-0.69	0.4874
a22	-39.0486	39.5660	-0.99	0.3237
a23	-28.5808	24.2438	-1.18	0.2385
a24	-38.0156	18.3937	-2.07	0.0388
a25	-80.9892	11.2162	-7.22	<.0001
a26	-134.702	7.3123	-18.42	<.0001
a27	-181.657	5.5473	-32.75	<.0001
m2c	13.31162	7.0927	1.88	0.0606
m3c	24.08949	9.3633	2.57	0.0101
m4c	75.31058	6.4185	11.73	<.0001
c3	-9.50543	8.3733	-1.14	0.2563
d3	72.52395	10.5955	6.84	<.0001
e3	-11.599	7.0743	-1.64	0.1011
z3	-0.07854	0.0120	-6.52	<.0001
ban3	4.428867	3.5195	1.26	0.2083
j3	0.252717	0.8537	0.30	0.7672
m5c	73.52843	6.7853	10.84	<.0001
m6c	88.64453	6.8339	12.97	<.0001
m7c	80.1943	7.2580	11.05	<.0001
m8c	66.02771	7.8936	8.36	<.0001
m9c	46.85506	12.4423	3.77	0.0002
m10c	66.02668	7.9835	8.27	<.0001
m11c	66.28623	7.3185	9.06	<.0001
m12c	56.23304	7.6970	7.31	<.0001

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
g9	67.41144	19.2155	3.51	0.0005
g10	39.73601	28.8137	1.38	0.1679
g11	-21.0504	21.8401	-0.96	0.3351
g12	558.8891	18.6298	30.00	<.0001
y7	-5.66447	4.3050	-1.32	0.1883
y8	0.704692	4.2036	0.17	0.8669
gg9	239.8607	18.8555	12.72	<.0001
gg10	-32.336	42.2718	-0.76	0.4443
gg11	52.31332	21.2328	2.46	0.0138
gg12	-9.58167	44.5992	-0.21	0.8299
mx3	292.8588	18.8186	15.56	<.0001
alpha4	-18.7797	1.1317	-16.59	<.0001
beta44	321.5528	22.5001	14.29	<.0001
a28	-104.017	5.4082	-19.23	<.0001
a29	-12.6613	6.7738	-1.87	0.0616
a30	15.08106	31.3063	0.48	0.6300
a31	27.08137	10.5599	2.56	0.0103
a32	-11.643	8.5998	-1.35	0.1758
a33	-50.0512	11.4461	-4.37	<.0001
a34	-47.8607	18.7008	-2.56	0.0105
a35	-42.7658	15.6618	-2.73	0.0063
a36	-45.3373	14.8511	-3.05	0.0023
m2d	-4.51991	5.9827	-0.76	0.4500
m3d	-65.9112	6.8534	-9.62	<.0001

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
m4d	-105.862	10.4807	-10.10	<.0001
c4	144.6868	5.4451	26.57	<.0001
d4	63.34511	14.9241	4.24	<.0001
e4	-21.5165	10.8826	-1.98	0.0480
z4	0.175844	0.00901	19.51	<.0001
ban4	26.39529	4.8647	5.43	<.0001
j4	-0.68427	1.0879	-0.63	0.5294
m5d	-110.925	11.0363	-10.05	<.0001
m6d	-101.526	9.7617	-10.40	<.0001
m7d	-81.7787	9.2704	-8.82	<.0001
m8d	-65.2131	8.8948	-7.33	<.0001
m9d	-67.5901	13.0403	-5.18	<.0001
m10d	-75.6812	10.7605	-7.03	<.0001
m11d	-72.0599	9.0557	-7.96	<.0001
m12d	-85.7258	9.3578	-9.16	<.0001
g13	81.26445	15.7395	5.16	<.0001
g14	-6.23203	27.6390	-0.23	0.8216
g15	17.3353	14.8453	1.17	0.2429
g16	55.87547	18.7577	2.98	0.0029
y10	3.35369	4.8717	0.69	0.4912
y11	4.087489	4.7712	0.86	0.3916
gg13	30.46449	19.0063	1.60	0.1090
gg14	24.31587	19.8184	1.23	0.2199
gg15	-5.57201	21.3636	-0.26	0.7942

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
gg16	-107.846	26.4839	-4.07	<.0001
mx4	-50.0805	20.3796	-2.46	0.0140

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Own supply elasticity of red gro	0.062539	0.0998	0.63	0.5308	(-0.5)*(beta12*sqrt(xpswgrp/xpredgrp)+beta13*sqrt(xpswsnap/xpredgrp) +beta14*sqrt(xl_pmisc/xpredgrp))*(xesf_a1/xredgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Own supply elasticity of sw grou	0.663517	0.0964	6.88	<.0001	(-0.5)*(beta12*sqrt(xpredgrp /xpswgrp)+beta23*sqrt(xpswsnap/xpswgrp) +beta24* sqrt(xl_pmisc/xpswgrp))*(xesf_a1/xswgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Own supply elasticity of sw snap	0.760069	0.0656	11.58	<.0001	(-0.5)*(beta13*sqrt(xpredgrp/xpswsnap)+beta23*sqrt(xpswgrp/xpswsnap) +beta34 *sqrt(xl_pmisc/xpswsnap))*(xesf_a1/xswsnaplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Own supply elasticity of l_miscl	0.891557	0.1040	8.57	<.0001	(-0.5)*(beta14*sqrt(xpredgrp/xl_pmisc)+beta24*sqrt(xpswgrp/xl_pmisc)+beta34*sqrt(xpswsnap/xl_pmisc))*(xesf_a1/xl_misclbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price red grouper with sw	0.114288	0.0984	1.16	0.2453	(0.5)*(beta12*sqrt(xpswgrp/xpredgrp))*(xesf_a1/xredgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price red grouper with sna	0.081609	0.0546	1.49	0.1353	(0.5)*(beta13*sqrt(xpswsnap/xpredgrp))*(xesf_a1/xredgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price red grouper with oth	-0.25844	0.0322	-8.03	<.0001	(0.5)*(beta14*sqrt(xl_pmisc/xpredgrp))*(xesf_a1/xredgrplbs)

Nonlinear FIML Estimates

Term	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
Cross-price sw grouper with red	0.08561	0.0737	1.16	0.2453	(0.5)*(beta12*sqrt(xpredgrp/xpswgrp))*(xesf_a1/xswgrplbs)

Nonlinear FIML Estimates

Term	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
Cross-price sw grouper with snap	-0.75224	0.0625	-12.03	<.0001	(0.5)*(beta23*sqrt(xpswsnap/xpswgrp))*(xesf_a1/xswgrplbs)

Nonlinear FIML Estimates

Term	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
Cross-price sw grouper with othe	0.003117	0.0372	0.08	0.9332	(0.5)*(beta24*sqrt(xl_pmisc/xpswgrp))*(xesf_a1/xswgrplbs)

Nonlinear FIML Estimates

Term	Estimate	Approx Std Err	t Value	Approx Pr > |t|	Label
Cross-price snappers with red gr	0.052463	0.0351	1.49	0.1353	(0.5)*(beta13*sqrt(xpredgrp/xpswsnap))*(xesf_a1/xswsnaplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price snapper with sw grou	-0.64559	0.0537	-12.03	<.0001	(0.5)*(beta23*sqrt(xpswgrp/xpswsnap))*(xesf_a1/xswsnaplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price snapper with other s	-0.16694	0.0331	-5.05	<.0001	(0.5)*(beta34*sqrt(xl_pmisc/xpswsnap))*(xesf_a1/xswsnaplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price other species with	-0.4483	0.0558	-8.03	<.0001	(0.5)*(beta14*sqrt(xpredgrp/xl_pmisc))*(xesf_a1/xl_misclbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price other species with	0.007217	0.0862	0.08	0.9332	(0.5)*(beta24*sqrt(xpswgrp/xl_pmisc))*(xesf_a1/xl_misclbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price other species with	-0.45047	0.0893	-5.05	<.0001	(0.5)*(beta34*sqrt(xpswsnap/xl_pmisc))*(xesf_a1/xl_misclbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Red Grouper Scale Elasticity	0.012048	0.0805	0.15	0.8810	(2*alpha1*xesf_a1+beta11+beta12*sqrt(xpswgrp/xpredgrp)+beta13*sqrt(xpswsnap/xpredgrp) +beta14*sqrt(xl_pmisc/xpredgrp))*(xesf_a1/xredgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Shallow water grouper Scale Elas	0.270357	0.1365	1.98	0.0476	(2*alpha2*xesf_a1+beta22+beta12*sqrt(xpredgrp/xpswgrp)+beta23*sqrt(xpswsnap/xpswgrp) +beta24*sqrt(xl_pmisc /xpswgrp))*(xesf_a1/xswgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Snappers Scale Elasticity	0.148952	0.1985	0.75	0.4531	(2*alpha3*xesf_a1+beta33+beta13*sqrt(xpredgrp/xpswsnap)+beta23*sqrt(xpswgrp/xpswsnap) +beta34*sqrt(xl_pmisc /xpswsnap))*(xesf_a1/xswsnaplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Other species Scale Elasticity	1.199253	0.2598	4.62	<.0001	(2*alpha4*xesf_a1+beta44+beta14*sqrt(xpredgrp/xl_pmisc)+beta24*sqrt(xpswgrp/xl_pmisc) +beta34*sqrt(xpswsnap/xl_pmisc))*(xesf_a1/xl_misclbs)

Test Results				
Test	**Type**	**Statistic**	**Pr > ChiSq**	**Label**
Test0	Wald	285.88	<.0001	alpha1, alpha2, alpha3, alpha4
Test1	Wald	283.04	<.0001	beta12, beta13, beta14, beta23, beta24,
Test2	Wald	66.28	<.0001	beta12, beta13, beta14
Test3	Wald	146.32	<.0001	beta12, beta23, beta24
Test4	Wald	183.72	<.0001	beta13, beta23, beta34
Test5	Wald	116.19	<.0001	beta14, beta24, beta34
Test6	Wald	49.07	<.0001	ban1,ban2,ban3,ban4
Test7	Wald	722.67	<.0001	c1,c2,c3,c4
Test8	Wald	192.30	<.0001	d1,d2,d3,d4
Test9	Wald	247.84	<.0001	e1,e2,e3,e4
Test10	Wald	9713.6	<.0001	g1,g2,g3,g4,gg1,gg2,gg3,gg4,mx1, g5,g6,
Test11	Wald	1.88	0.7583	j1,j2,j3,j4
Test12	Wald	2747.7	<.0001	z1,z2,z3,z4
Test13	Wald	1332.2	<.0001	m2a, m3a, m4a, m5a, m6a, m7a, m8a, m9a,
Test14	Wald	2679.8	<.0001	a1,a2,a3,a4,a5,a6,a7,a8,a9,a10,a11,a12,
Test15	Wald	166.37	<.0001	y1,y2, y4,y5, y7,y8 ,y10,y11

Number of Observations		Statistics for System	
Used	19503	**Log Likelihood**	-567851
Missing	0		
Sum of Weights	7482		

Heteroscedasticity Test

Equation	Test	Statistic	DF	Pr > ChiSq	Variables
redgrplbs	White's Test	1568	683	<.0001	Cross of all vars
swgrplbs	White's Test	2254	683	<.0001	Cross of all vars
swsnaplbs	White's Test	2073	683	<.0001	Cross of all vars
l_misclbs	White's Test	1551	683	<.0001	Cross of all vars

Chapter 2

Appendix B: Longline model parameter estimates

Model Summary	
Model Variables	3
Parameters	107
Equations	3
Number of Statements	194

Note: The parameter beta12 is shared by 2 of the equations to be estimated.

Note: The parameter beta13 is shared by 2 of the equations to be estimated.

Note: The parameter beta23 is shared by 2 of the equations to be estimated.

The 3 Equations to Estimate	
redgrplbs =	F(alpha1, beta11, beta12, beta13, a1, a2, a3, a4, a5, a6, a7, a8, a9, c1, d1, e1, z1, j1, m2a, m3a, m4a, m5a, m6a, m7a, m8a, m9a, m10a, m11a, m12a, g1, g2, g3, mx1, y2, y3)
swgrplbs =	F(beta12, alpha2, beta22, beta23, a10, a11, a12, a13, a14, a15, a16, a17, a18, c2, d2, e2, z2, j2, m2b, m3b, m4b, m5b, m6b, m7b, m8b, m9b, m10b, m11b, m12b, g5, g6, g7, mx2, y5, y6)
l_misclbs =	F(beta13, beta23, alpha3(esf_a2), beta33(esf_a1), a19, a20, a21, a22, a23, a24, a25, a26, a27, c3, d3, e3, z3, j3, m2c, m3c, m4c, m5c, m6c, m7c, m8c, m9c, m10c, m11c, m12c, g9, g10, g11, mx3, y8, y9)

Observations will be weighted by	inv

NOTE: At FIML Iteration 0 CONVERGE=0.001 Criteria Met.

Data Set Options	
DATA=	NEW9
OUT=	LREST
OUTEST=	LFIN

Minimization Summary	
Parameters Estimated	102
Method	Gauss
Hessian	GLS
Covariance Estimator	Cross
Iterations	0

Final Convergence Criteria	
R	7.805E-6
PPC(beta12)	0.001566
RPC	.
Object	.
Trace(S)	245903.3
Gradient norm	2.5E-12
Log likelihood	-115304

Observations Processed	
Read	4335
Solved	4335

Nonlinear FIML Summary of Residual Errors							
Equation	DF Model	DF Error	SSE	MSE	Root MSE	R-Square	Adj R-Sq
redgrplbs	34	4301	4.3314E8	100707	317.3	0.3807	0.3759
swgrplbs	34	4301	1.2337E8	28684.2	169.4	0.2073	0.2012
l_misclbs	34	4301	5.0948E8	118456	344.2	0.1970	0.1908

Nonlinear FIML Parameter Estimates				
Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
alpha1	-11.0978	1.4775	-7.51	<.0001
beta11	584.4821	123.4	4.74	<.0001
beta12	-129.741	99.5708	-1.30	0.1926
beta13	-65.3452	25.5266	-2.56	0.0105
a1	52.891	169.7	0.31	0.7553
a2	90.27728	54.5083	1.66	0.0978
a3	132.0686	50.4295	2.62	0.0089
a4	148.4518	48.2471	3.08	0.0021
a5	217.1422	46.3563	4.68	<.0001
a6	193.8976	48.5302	4.00	<.0001
a7	47.28764	58.7311	0.81	0.4208
a8	17.37914	53.9162	0.32	0.7472
a9	-56.6514	84.7403	-0.67	0.5038
c1	-184.158	49.9112	-3.69	0.0002
d1	-384.685	125.1	-3.07	0.0021
e1	93.81104	22.3329	4.20	<.0001
z1	-0.22795	0.0525	-4.34	<.0001

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
j1	0.173122	2.2549	0.08	0.9388
m2a	-55.1146	29.3979	-1.87	0.0609
m3a	-100.634	31.7367	-3.17	0.0015
m4a	-47.519	24.3958	-1.95	0.0515
m5a	-90.6397	28.3590	-3.20	0.0014
m6a	-61.3235	24.6018	-2.49	0.0127
m7a	-104.946	25.5661	-4.10	<.0001
m8a	-96.2745	28.8022	-3.34	0.0008
m9a	-88.1003	36.6604	-2.40	0.0163
m10a	-15.9322	25.7010	-0.62	0.5354
m11a	-11.1121	27.6592	-0.40	0.6879
m12a	-30.6702	30.4477	-1.01	0.3138
g1	-45.754	33.1444	-1.38	0.1675
g2	12.29663	39.5525	0.31	0.7559
g3	-15.4488	27.1363	-0.57	0.5692
mx1	-93.1365	45.3558	-2.05	0.0401
y2	-25.6861	18.9674	-1.35	0.1757
y3	-20.6623	16.4813	-1.25	0.2100
alpha2	0.564535	0.6456	0.87	0.3820
beta22	204.901	94.2646	2.17	0.0298
beta23	12.51757	18.0657	0.69	0.4884
a10	66.91073	37.0232	1.81	0.0708
a11	46.06344	22.1802	2.08	0.0379
a12	52.97429	23.0811	2.30	0.0218

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
a13	77.85235	22.1556	3.51	0.0004
a14	78.58377	21.5591	3.65	0.0003
a15	99.40517	21.9136	4.54	<.0001
a16	67.28472	25.0362	2.69	0.0072
a17	40.38138	23.6707	1.71	0.0881
a18	-20.236	33.4866	-0.60	0.5457
c2	-86.8883	41.0684	-2.12	0.0344
d2	-136.85	88.4986	-1.55	0.1221
e2	22.43947	12.2512	1.83	0.0671
z2	-0.0846	0.0267	-3.17	0.0016
j2	-0.03308	1.4677	-0.02	0.9820
m2b	-29.4669	14.1813	-2.08	0.0378
m3b	-24.5222	14.8708	-1.65	0.0992
m4b	-15.634	11.7481	-1.33	0.1833
m5b	-35.4489	13.1662	-2.69	0.0071
m6b	-16.8242	11.7752	-1.43	0.1531
m7b	-49.0264	13.0579	-3.75	0.0002
m8b	-58.6691	16.2095	-3.62	0.0003
m9b	-64.2687	22.2246	-2.89	0.0038
m10b	-27.7629	14.0324	-1.98	0.0479
m11b	-22.873	13.2705	-1.72	0.0849
m12b	-15.7292	14.8910	-1.06	0.2909
g5	40.59907	13.3010	3.05	0.0023
g6	-80.8546	30.7554	-2.63	0.0086

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
g7	-11.8162	12.2766	-0.96	0.3359
mx2	30.37003	20.3107	1.50	0.1349
y5	-24.5433	9.1188	-2.69	0.0071
y6	-8.35394	8.2613	-1.01	0.3120
alpha3	-7.15934	1.9854	-3.61	0.0003
beta33	394.4959	47.6186	8.28	<.0001
a19	19.41328	30.5729	0.63	0.5255
a20	-274.233	16.8985	-16.23	<.0001
a21	-221.609	30.3789	-7.29	<.0001
a22	-232.284	34.8709	-6.66	<.0001
a23	-307.635	33.5191	-9.18	<.0001
a24	-316.924	51.2166	-6.19	<.0001
a25	-136.346	34.6652	-3.93	<.0001
a26	-95.8506	37.2141	-2.58	0.0100
a27	-34.3777	47.3596	-0.73	0.4679
c3	238.5754	24.7573	9.64	<.0001
d3	373.1588	61.1053	6.11	<.0001
e3	-84.1884	39.6717	-2.12	0.0339
z3	0.138661	0.0337	4.12	<.0001
j3	-3.55343	3.5816	-0.99	0.3212
m2c	-21.0557	29.9102	-0.70	0.4815
m3c	80.33252	28.2248	2.85	0.0044
m4c	42.93565	26.5783	1.62	0.1063
m5c	29.77663	30.6510	0.97	0.3314

Nonlinear FIML Parameter Estimates				
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**
m6c	40.57716	31.8482	1.27	0.2027
m7c	122.15	22.3264	5.47	<.0001
m8c	39.85997	36.6765	1.09	0.2772
m9c	117.5159	49.9723	2.35	0.0187
m10c	32.29677	40.6083	0.80	0.4265
m11c	10.38093	40.5194	0.26	0.7978
m12c	9.758166	39.7091	0.25	0.8059
g9	13.01238	36.5397	0.36	0.7218
g10	32.14804	53.8406	0.60	0.5505
g11	47.73718	29.4459	1.62	0.1051
mx3	397.4728	27.7559	14.32	<.0001
y8	38.54461	20.6815	1.86	0.0624
y9	-3.35261	19.5010	-0.17	0.8635

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Own-price supply elasticity of r	0.339924	0.1910	1.78	0.0752	(-0.5)*(beta12*sqrt(xpswgrp/xpredgrp)+beta13*sqrt(xl_pmisc/xpredgrp))*(xesf_a1/xredgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Own-price supply elasticity of s	0.497411	0.4192	1.19	0.2355	(-0.5)*(beta12*sqrt(xpredgrp /xpswgrp)+beta23*sqrt(xl_pmisc/xpswgrp))*(xesf_a1/xswgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Own-price supply elasticity of o	0.219431	0.1028	2.14	0.0328	(-0.5)*(beta13*sqrt(xpredgrp /xl_pmisc)+beta23*sqrt(xpswgrp/xl_pmisc))*(xesf_a1/xl_misclbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price red grouper wrt sw g	-0.24523	0.1882	-1.30	0.1926	(0.5)*(beta12*sqrt(xpswgrp/xpredgrp))*(xesf_a1/xredgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price red grouper wrt misc	-0.09469	0.0370	-2.56	0.0105	(0.5)*(beta13*sqrt(xl_pmisc/xpredgrp))*(xesf_a1/xredgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price sw grouper wrt red g	-0.54191	0.4159	-1.30	0.1926	(0.5)*(beta12*sqrt(xpredgrp/xpswgrp))*(xesf_a1/xswgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price sw grouper wrt misc	0.044496	0.0642	0.69	0.4884	(0.5)*(beta23*sqrt(xl_pmisc/xpswgrp))*(xesf_a1/xswgrplbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price misc wrt red	-0.27869	0.1089	-2.56	0.0105	(0.5)*(beta13*sqrt(xpredgrp /xl_pmisc))*(xesf_a1/xl_misclbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Cross-price misc wrt sw grouper	0.059262	0.0855	0.69	0.4884	(0.5)*(beta23*sqrt(xpswgrp/xl_pmisc))*(xesf_a1/xl_misclbs)

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Scale of red grouper	0.700795	0.1950	3.59	0.0003	(xesf_a1/xredgrplbs)*(2*alpha1*xesf_a1+ beta11+beta12*sqrt(xpswgrp/xpredgrp) +beta13*sqrt(xl_pmisc/xpredgrp))

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Scale of sw grouper	0.989693	0.2403	4.12	<.0001	(xesf_a1/xswgrplbs)*(2*alpha2*xesf_a1+beta22+beta12*sqrt(xpredgrp/xpswgrp) +beta23*sqrt(xl_pmisc /xpswgrp))

Nonlinear FIML Estimates					
Term	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
Scale of misc	1.586286	0.3021	5.25	<.0001	(xesf_a1/xl_misclbs)*(2*alpha3*xesf_a1+beta33+beta13*sqrt(xpredgrp/xl_pmisc) +beta23*sqrt(xpswgrp/xl_pmisc))

Test Results				
Test	**Type**	**Statistic**	**Pr > ChiSq**	**Label**
Test0	Wald	92.72	<.0001	alpha1, alpha2, alpha3
Test1	Wald	8.78	0.0324	beta12, beta13, beta23
Test2	Wald	107.91	<.0001	beta11,beta22,beta33
Test3	Wald	8.41	0.0149	beta12, beta13
Test4	Wald	2.13	0.3441	beta12, beta23
Test5	Wald	6.86	0.0324	beta13, beta23
Test6	Wald	45.64	<.0001	z1,z2,z3
Test7	Wald	103.62	<.0001	c1,c2,c3
Test8	Wald	46.05	<.0001	d1,d2,d3
Test9	Wald	19.14	0.0003	e1,e2,e3
Test10	Wald	1.00	0.8024	j1,j2,j3
Test11	Wald	95.25	<.0001	m2a, m3a, m4a, m5a, m6a, m7a, m8a, m9a,
Test12	Wald	341.58	<.0001	g1,g2,g3, g5,g6,g7 ,g9,g10,g11,mx1,mx2,

Test Results				
Test	**Type**	**Statistic**	**Pr > ChiSq**	**Label**
Test13	Wald	480.03	<.0001	a1,a2,a3,a4,a5,a6,a7,a8,a9,a10,a11,a12,
Test14	Wald	16.71	0.0104	y2,y3 ,y5,y6, y8,y9

Number of Observations		Statistics for System	
Used	4335	**Log Likelihood**	-115304
Missing	0		
Sum of Weights	351.9400		

Heteroscedasticity Test					
Equation	**Test**	**Statistic**	**DF**	**Pr > ChiSq**	**Variables**
redgrplbs	White's Test	261.8	462	1.0000	Cross of all vars
swgrplbs	White's Test	352.0	462	1.0000	Cross of all vars
l_misclbs	White's Test	1187	462	<.0001	Cross of all vars