A General Equilibrium Demand Model for Living Marine Resources: An Application of General Equilibrium and Common Property Resource Theory to the U.S. Seafood Sector

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File Manuscript 116

August 1971

U.S. NATIONAL MARINE FISHERIES SERVICE
ECONOMIC RESEARCH LABORATORY

ABSTRACT

Title of Thesis: A General Equilibrium Demand Model for Living Marine Resources: An Application of General Equilibrium and Common Property Resource Theory to the U.S. Seafood Sector

Richard F. Fullenbaum, Doctor of Philosophy, 1971

Thesis directed by: Professor Frederick W. Bell

The purpose of this study is to extend the traditional model of common property resource exploitation to a more general equilibrium frame of reference, and to examine policy implications in the light of the extended analysis. The most pronounced modification consists of the specification of cross partial price derivatives of demand between the major species of seafood consumed in the United States.

The estimation procedure integrates both time series and cross-sectional results in deriving all relevant price and income parameters. The time series analysis employs a technique originated by Powell (26), in which a series of linear expenditure functions--based upon the assumption of the existence of a continuously differentiable <u>additive</u> utility function--is estimated. Seafood is treated as a separate commodity in the budget constraint, and an implicit test of the additivity assumption in this context is devised. The method of estimation involves an iterative technique in which prior restrictions on the system give maximum likelihood estimators and the same

estimates as would be obtained using two-stage least squares. The major purpose of the time series component is to provide a forecasting equation for expenditures on all seafood commodities, which takes into account anticipated budget constraints and expenditures on all other commodities. The major parameters that are derived include $\hat{b}_F$ - the expenditure coefficient for all seafood, and $\hat{\gamma}$. $\hat{\gamma}$ is equal to the following:

$$(1) \quad \hat{\gamma} = \lambda / \frac{\partial \lambda}{\partial y},$$

where λ is the marginal utility of income, and y is income. Another related purpose of the time series analysis is to provide a control total for the sum of consumer expenditures for individual species. The aggregate seafood expenditure parameter $\hat{b}_F$, is 'distributed' across species on the basis of cross sectional income coefficients for individual species which are constrained such that their sum is equal to $\hat{b}_F$.

The major purpose of the cross-sectional component of the study--in addition to the estimation of individual species income coefficients--is to select a set of twenty-eight independently estimated reliable own and cross price derivatives, from which sixty-four price derivatives are obtained (i.e., eight species, 8x8=64 price derivatives). In order to derive these demand parameters, the time series parameter $\hat{\gamma}$ is utilized. The estimates follow directly from tenets of utility maximization.

This completes the demand aspect of the study. On the supply side, species are broken down according to proximity to their universal constraints at maximum sustainable yield. Those species which are at or near MSY are classified as constrained species; those which are not close to MSY or for which artificial techniques of cultivation have been developed are classified as unconstrained species. Forecasts of consumption are made under the assumption of perfect elasticity of supply for <u>all</u> species. Then, as a result of forecasting far enough into the future such that market clearance at MSY is a reasonable assumption for the constrained species, quantity adjustments--equal to the difference between quantity consumed under conditions of perfect elasticity and quantity consumed at MSY--are calculated. Given these quantity adjustments, relative price changes for the constrained species may be obtained.

The conclusion reached is that, within a general equilibrium framework, the rate of price increase due to the imposition of supply constraints is considerably dampened. Furthermore, only slight modifications of the market mechanism are needed in order to prevent excessive entry of capital and labor into fisheries which are being exploited at maximum sustainable yield. In other words, since the rate of entry of excessive inputs is tied to the rate of change in relative prices, a policy such as a quota, when evaluated within a general equilibrium framework, will yield an input combination such that the level of redundant capital and labor is negligible.

A GENERAL EQUILIBRIUM DEMAND MODEL FOR LIVING MARINE RESOURCES: AN APPLICATION OF GENERAL EQUILIBRIUM AND COMMON PROPERTY RESOURCE THEORY TO THE U.S. SEAFOOD SECTOR

by
Richard Fred Fullenbaum

Dissertation submitted to the Faculty of the Graduate School
of the University of Maryland in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
1971

TO SHEILA

ACKNOWLEDGMENTS

I would like to express my appreciation to the many people who, in one way or another, assisted in the completion of this dissertation. First, I would like to thank my major advisor, Dr. Frederick W. Bell, whose suggestions and patient guidance were extremely helpful, especially when 'the going got rough.' I have also profited by advice (and discussion) from the rest of the dissertation committee: Dr. John Cumberland, Dr. Darrel A. Nash, Dr. Paul Meyer, and Dr. Neil Murphy. Ernest Carlson, made some constructive comments on an earlier draft.

I would also like to express my sincere gratitude to William Gaynor, whose programming skills expedited the data processing and regression routines. Thanks also goes to Leonard Ginn for statistical compilations and to Mrs. Shelva Page and Miss Nancy Aldrich who bore the brunt of the typing and editing of the final draft.

Last, but by no means least, I am grateful to my wife Sheila who typed several of the draft manuscripts, endured the ravings of a 'lunatic', and most importantly, encouraged and never lost confidence.

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CHAPTER I

LITERATURE REVIEW AND SOME INITIAL ASSUMPTIONS

> He was an old man who fished alone in a skiff in the Gulf Stream and he had gone eighty-four days now without taking a fish. In the first forty days a boy had been with him. But after forty days without a fish the boy's parents had told him that the old man was now definitely and finally "salao," which is the worst form of unlucky, and the boy had gone at their orders in another boat which caught three good fish the first week. It made the boy sad to see the old man come in each day with his skiff empty and he always went down to help him carry either the coiled lines or the gaff and harpoon and the sail that was furled around the mast. The sail was patched with the flour sacks and, furled, it looked like the flag of permanent defeat . . .
>
> E. Hemingway, The Old Man and the Sea

1. Introduction

The sea and its resources have formed the basis of renewed attention from the world community. The pressure of world population expansion has led to more intensive exploitation and, at the same time, to increasing concern over the marine environment. However, the living marine resources of the sea are common property in nature and therefore subject to technological externalities which complicate the process of resource use. The economic analysis of common property resources, in general, and marine resources as a special case, has proliferated into a subset of the literature related to social externalities. It is the purpose of this study to expand upon this growing literature with a theoretical development not previously applied to this area. Hopefully, the empirical content and the estimation of parameters which have hitherto not been identified will lay the foundation for a more sophisticated approach, especially in the context of substantive policy applications. The most important modification which this research attempts is the addition of the general equilibrium framework to problems traditionally handled in a partial frame of reference. More specifically, we will examine the impact upon prices and the possible allocative significance of given resource constraints in a general equilibrium setting. By the resource constraint we mean the supply constraint imposed by the biological yield function (at maximum sustainable yield) that precludes the expansion of output per unit of time for certain species without eliminating the inflow of new economic resources (i.e., capital and labor) attracted by positive economic profits.

The basic aim of this chapter is to review some of the traditional literature and to discuss the initial assumptions which form the background of the model presented in chapter two. Section two presents a brief literature review and formalizes the previous literature into one complete model. Section three presents some of the modifications and assumptions that will be made in this study.

2. Literature Review and Model Development

The works of Gordon (16), Scott (31), Crutchfield and Zellner (10) and Plourde (25) integrated with the biological theories formulated by Schaefer (29) *et al* (30) provide the foundation for a unified, generalized theory of marine exploitation.[1] Our discussion of these individual contributors will be presented within the context of the two theoretical issues developed in the literature, i.e., the static externalities generated by the common property nature of the resource, and, secondly, the more dynamic implications of the use of a proper social discount rate.

Gordon's article represents the pioneer work with respect to common property resources. It is particularly noteworthy that much of what has followed this seminal paper represents a refinement of the basic ideas developed by Gordon. For example, the interallocation of effort between fishing grounds, the notion of an ecological equilibrium as distinct from an economic equilibrium -- these basic strands of thought, as well as the common property externality, are all contained in this paper and were all formalized in subsequent works. The analysis is set forth under a number of

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[1]The article by Vernon L. Smith entitled "Economics of Production from Natural Resources" (AER: Volume LVII, June 1968) has been intentionally excluded from our survey of the literature because it adds little and tends to obscure the major theoretical issues. In particular, the cost function of the firm is misspecified, i.e., Smith confuses the difference between average cost per firm per unit of time and total cost per firm per unit of time. Another problem with the Smith model is its inherent dynamic instability. For a conceptual comparison between Smith's work and the traditional literature, see "Economics of Production from Natural Resources: Comment," by Richard F. Fullenbaum, Ernest W. Carlson, and Frederick W. Bell, American Economic Review (forthcoming), and "On Models of Commercial Fishing: A Defense of the Traditional Literature," the same authors, Journal of Political Economy (forthcoming).

simplifying assumptions: a large number of fishermen are presumed to be exploiting any given fishing ground; a fishing ground is assumed to have a fixed geographical location; the quantity of fish emanating from any one ground is so small relative to the total level of fish produced that price is given; finally, pecuniary externalities are assumed to be nonexistent. Given these assumptions, Gordon's major hypothesis is that in the long run the rent, which is a return to society for the scarce fishery resource, is completely dissipated precisely because no one owns the resource. The important elements of the Gordon analysis may be summarized in Figure (1.1). The latter presents the long-run relationship between total revenue and total cost as a function of fishing effort. Under the condition of free-access, equilibrium is established when total revenue equals total cost. However, an optimum in this context, i.e., marginal cost pricing, occurs where the slope of the total revenue function is equal to the slope of the total cost function. Diminishing returns with respect to the resource, coupled with the common property externality, causes exploitation to be continued until TR is equal to TC.

The preceding analysis was just a particular example of a more general marine model. The underlying structure of that model includes a distinct biological theory, and some fundamental assumptions with respect to the economic behavior involved in the exploitation of the resource. The

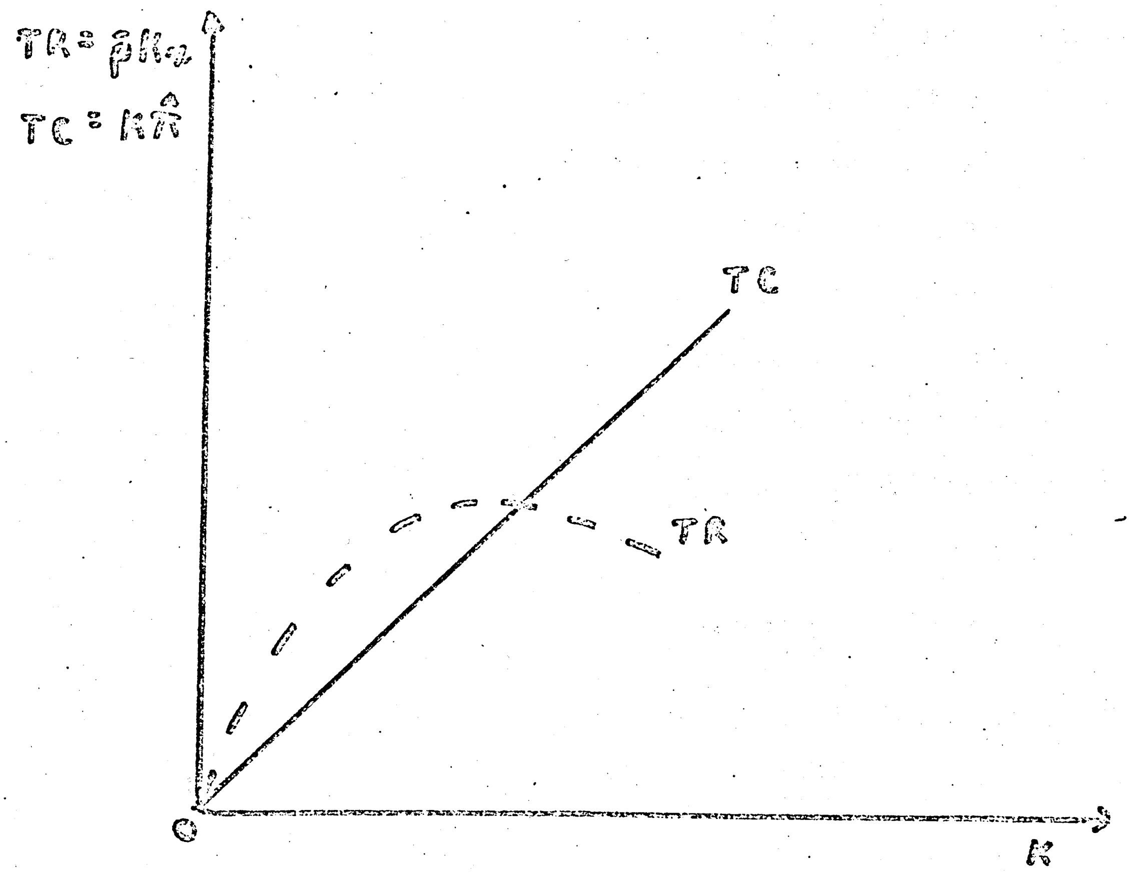

FIGURE 1.1

biological dynamics of a living marine resource may be depicted as follows:

$$(1.1) \quad \frac{1}{X}\frac{dX}{dt} = q(X) + g(X) - M(X) - F(K) + u,$$

where X is the population, i.e., the biomass, q is the recruitment rate function, g is the growth rate function, and M is the natural mortality rate function. F(K) is the rate of loss of the biomass caused by fishing, and u is a stochastic term with an expected value equal to zero. Let us abstract from fishing pressure by assuming F(K) = 0. One of the more commonly used exact specifications of (1.1) was that developed by Lotka (22) and Volterra (40), first applied to fishing by Schaefer, and often referred to as the logistic[2]:

$$(1.2) \quad \frac{1}{X}\frac{dX}{dt} = k(L-X)$$

k and L are biological parameters.

$$(1.3) \quad \frac{dX}{dt} = kLX - kX^2 \equiv aX - bX^2$$

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[2] If we take (1.2) and multiply by X, we obtain

$$(2.1)' \quad \frac{dX}{dt} = kLX - kX^2$$

Integrating over (1.1)' we derive:

$$(2.2)' \quad \int kLX(t) - k(X(t))^2 \, dt = \frac{L}{1 + b'e^{-kLt}}$$

The latter is referred to as the logistic. The limit of (2.2)' as $t \to \infty$ is equal to L. We can derive the same solution if we set (2.1)' equal to zero and solve for the non-zero equilibrium biomass.

When (1.2) is multiplied by X, a net yield relationship which is quadratic in X is formed.

Figure (1.2) plots the relationship between X and $\frac{dX}{dt}$. Without exploitation by man, the biomass will reach a natural upper limit. That is, beyond this limit natural forces will tend to reduce the biomass and vice versa when no fishing occurs. Note that $\underline{X}$ is unstable in the sense that the slightest increase in the population will push the equilibrium biomass to $\bar{X}$ which is stable. X^0 is the fish stock consistent with maximum sustainable yield, i.e., where $\frac{dX}{dt}$ is at a maximum. In terms of the parameters of (1.3) $\underline{X}$ is equal to zero, $\bar{X}$ is equal to $\frac{a}{b}$ and X^0 is equal to $\frac{a}{2b}$. This, of course, represents one of the more simplistic biological models. More sophisticated theories employing a richer assortment of complex assumptions have also been developed.[3]

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[3] A more refined treatment is developed by Beverton and Holt (6). The following relations were specified:

(3.1)' $N_t = R \exp\left[-M(t_c - t_r)\right] \exp-(F+M)(t-t_c)$

(3.2)' $P_t = N_t w_t$

(3.3)' $\frac{dy}{dt} = FN_t w_t = F[R \exp-M(t_c - t_r)(\exp-F+M)(t-t_c))]$

(3.4)' $Y = \int_{tc}^{tm} FN_t w_t \, dt$

In the above set of equations, N_t represents the number of fish at age t, w is weight per fish at age t, P_t is the

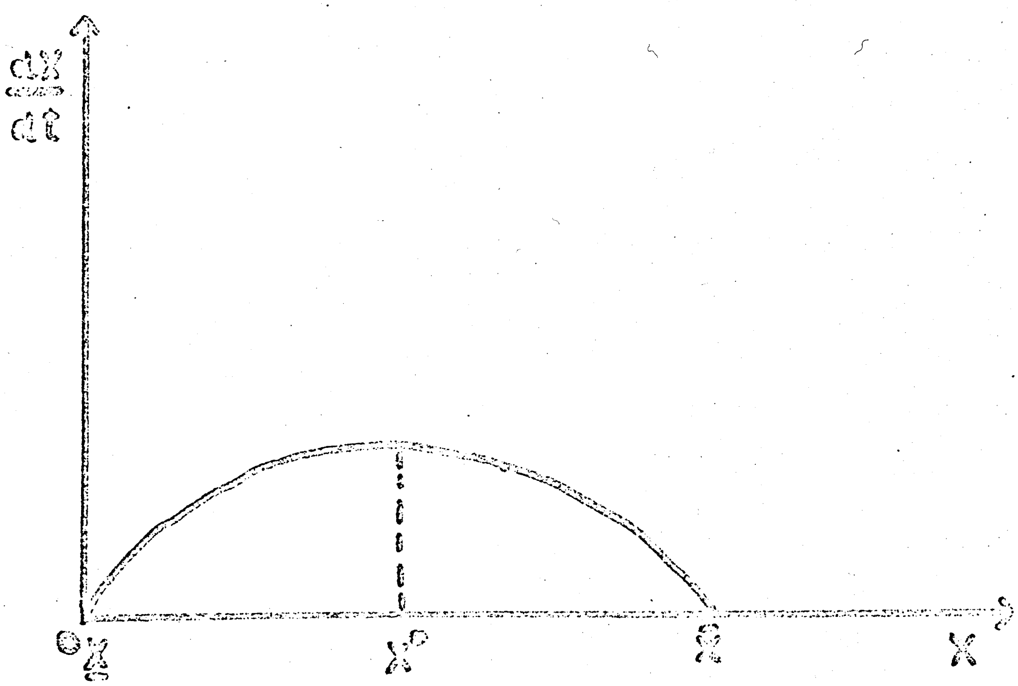

FIGURE 1.2

The introduction of fishing pressure is normally assumed to change the instantaneous rate of increase by the amount harvested. Thus, (1.3) becomes,

(1.4) $$\frac{dX}{dt} = aX - bX^2 - Kx,$$

where Kx is equal to the harvest rate, and K, x, are the number of vessels and output per vessel respectively.

The economic component of the marine resource model includes an industry production function, cost function, and profit function, i.e.,

(1.5) $$Kx = Kg(X, K)$$

(1.6) $$C = K\hat{\pi} \quad ,$$

(1.7) $$\pi = p(Kx)Kx - C$$

In the above set of equations, C is total industry cost, $\hat{\pi}$ is opportunity cost per vessel, π is equal to total industry

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biomass at t, R is the number of recruits, t_r and t_c are respectively age at recruitment to catchable stock and age at minimum size of allowable capture, F is the catchability coefficient, $\frac{dy}{dt}$ is the rate of catch, and Y is the total catch from a given year class during its entire life. In equilibrium, the total annual catch from the population is equal to the catch of a year class over its entire life. F varies with the degree of fishing intensity.

Another alternative to the logistic originated by William W. Fox, Jr. (12) is the Exponential Surplus Yield Model which used the Gompertz growth equation

(3.5)' $f(\bar{p}) = K(\log P_\infty - \log \bar{P})$, where $\bar{P}$ is the mean annual population, P_∞ is the environmentally limited maximum population, k is the constant of the rate of population size, and $f(\bar{p})$ is the growth of the population. Still another yield function was that formulated by Pella and Tomlinson, in which $\dot{X} = aX - bX^m$

profits, and p is price. The movement of capital into or out of the industry per unit of time under pure competition follows the condition, $\frac{dK}{dt} \gtrless 0$, according as $\pi \gtrless 0$.

The basic externality enters via the production function specified in (1.5). That is, $\frac{\partial x}{\partial X} \equiv g_1 > 0$ defines the resource externality, and $\frac{\partial x}{\partial K} \equiv g_2 < 0$ defines the crowding externality caused by congestion of vessels. Most of the traditional writers, including Scott and Gordon, assume that $g_2 = 0$, and that the production function is of the specific form,

$$(1.8) \quad Kx = rKX,$$

where r is a technological parameter. While this particular form is perhaps naive, its use does not change any of the qualitative conclusions concerning the potential misallocation of resources.[4] Given the logistic growth function and the "constant returns" production function in (1.8), we may solve for X in terms of K under conditions of ecological equilibrium, i.e, for the condition that $\frac{dX}{dt} = 0$. Then, resubstituting for X in (1.8), we get,

$$(1.9) \quad Kx = \frac{ar}{b} K - \frac{r^2}{b} K^2 \equiv \alpha K - \beta K^2$$

Multiplying (1.9) by a constant price $\bar{p}$ (assumed in the Scott-Gordon analysis), we derive the total revenue function plotted in figure (1.1).

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[4] The production function may more realistically take the form $Kx = rK^{\mu} X$, $0<\mu<1$, without changing any of Gordon's basic conclusions.

The traditional conclusions may be recast into more conventional economic terms by mapping the relationship between K and Kx, and then obtaining the relationship between Kx and marginal cost and average cost. Marginal cost (MC) and average cost (AC) are respectively defined as,

$$(1.10) \quad MC = \hat{\pi} \Big/ \frac{\partial Kx}{\partial K} ,$$

$$(1.11) \quad AC = \hat{\pi} \Big/ \frac{Kx}{K} .$$

These two functions, along with a perfectly elastic demand curve, are plotted in Figure (1.3). As a result of free-entry, exploitation is continued until price is equal to average cost -- not marginal cost. This method of illustrating the misallocation has been used by Copes (8), and functions (1.10) and (1.11) and the extent of the misallocation implied by their difference have been measured by Bell (3).[5]

Given that price is parametric, one of the most frequently mentioned "corrective" devices -- discussed, not for its feasibility, but because of the obvious comparison drawn in order to find an optimal solution -- is the adjustment of the institutional arrangement from free-entry to sole ownership. It can easily be demonstrated that as a result of this

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[5] The importance of adopting this framework, rather than the Scott-Gordon revenue cost analysis, is that it is more adaptable to situations in which the demand curve is less than perfectly elastic. Under those circumstances, marginal cost pricing is not synonymous with maximizing the rent accruing to the resource; the preoccupation with the latter is a major shortcoming in the traditional literature.

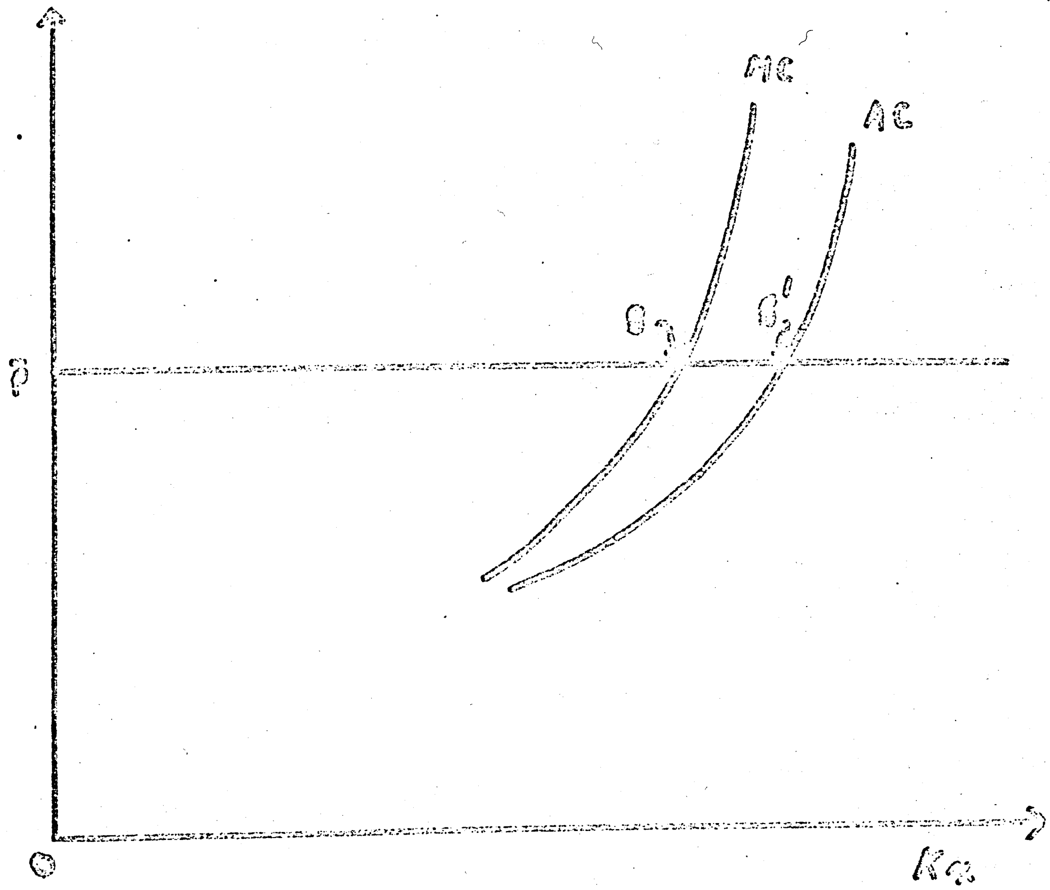

FIGURE 1.3

change, the externality is internalized, and the misallocation eliminated. The profit function for the sole owner of the fleet would now be:

$$(1.12) \quad \pi = \bar{p}Kx - K\hat{\pi}$$

Substituting (1.9) into (1.12), differentiating with respect to K, setting the resultant differential equation equal to zero, and solving for the profit-maximizing level of capital, K^* we find that this provides the same solution as when the right hand side of (1.10) is set equal to $\bar{p}$. Thus, point B in figure (1.3) represents the new equilibrium position, whereas B^1 depicts the solution under conditions of free-entry.[6] Another policy prescription which would simulate the sole ownership result within a free-access competitive framework is the imposition of a tax per boat:

$$(1.13) \quad T_k = \frac{\bar{p}K^*x^* - K^*\hat{\pi}}{K^*} \equiv \bar{p}x^* - \hat{\pi}$$

where x^* is the optimal level of output per boat and all other symbols are as defined above.[7]

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[6] When price is not constant, then, of course, there is an additional loss in consumers' surplus which is not incurred when price is parametric. This does not change any of the qualitative conclusions.

[7] For the case in which p is not parametric, the solution for K^* and T_k are much more complicated. For example, when price is a function of quantity, then the tax, in general terms, would be formulated as:

$$(7.1)' \quad p(K^*)x^* - \hat{\pi}$$

The optimal level of boats would be found from the expression,

$$(7.2)' \quad p(K) = \hat{\pi} \Big/ \frac{\partial Kx}{\partial K}$$

Under conditions of optimal exploitation, some results governing the equilibrium biomass can easily be obtained. These results were first formalized by Crutchfield and Zellner in their work on the Pacific Halibut fishery. We may respecify the profit function in terms of the biomass (for $\frac{dX}{dt} = 0$), by setting the production function rKX equal to the logistic growth relationship, and solving for K in terms of X. Thus,

$$(1.14) \quad \pi = \bar{p}\,(aX - bX^2) - \hat{\pi}\,(a/r - b/r\,X)$$

Differentiating (1.14) and solving for the profit-maximizing level of the biomass, we find that

$$(1.15) \quad X^*_s = a/2b + \hat{\pi} / 2\,r\,\bar{p}$$

The limit of (1.15) as $\bar{p} \to \infty$ is equal to $\frac{a}{2b}$. This is the level of the biomass consistent with maximum sustainable yield, which is defined either as a maximum of (1.9) or of (1.3). On the other hand, under conditions of free-entry, we may solve for the zero-profit level of the biomass by setting (1.14) equal to zero, and solving for X:

$$(1.16) \quad X^*_c = \hat{\pi} / 2\,r\,\bar{p}$$

The limit of (1.16) as $\bar{p} \to \infty$ is equal to zero. Thus, extinction of the resource is a possibility with pure competition. Related to this latter proposition is the axiom that unlike sole ownership -- which precludes operating in the area of negative marginal productivity with respect to an increase

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It is very likely that we may not be able to solve for K^* explicitly in (7.2)' so that K^* would have to be approximated using numerical methods.

in the fleet -- free-entry may generate a situation in which the biomass is less than that consistent with maximum sustainable yield. In this case, the $\frac{\partial Kx}{\partial K} < 0$, and marginal cost is negative; in addition, the operation of the fishery will be maintained in the backward sloping portion of the industry average cost curve.

This completes our review of the common property externality. The analysis has been set forth under some highly simplifying assumptions: the particular biological theory is naive in that it does not take into account ecological interdependence among species; the specified industry production function ignored possible crowding externalities, i.e., the static stock externality caused by the interaction of a larger number of boats rather than the scarcity of the resource; the models were partial in nature and thus glossed over economic interdependence among species both on the demand and supply side; finally, the analysis presupposed that the biomass was instantaneously in equilibrium. It is with respect to this last assertion that the second major theoretical development comes into perspective. This aspect was first mentioned by Scott, and more fully explored by Crutchfield and Zellner. Let us abstract from the externality issue by assuming sole ownership and that price is equal to $\bar{P}$. We may illustrate the importance of not having the biomass in equilibrium, i.e., $\frac{dX}{dt} \neq 0$, by presenting a counter-example. Let us respecify (1.14) so that the profits are defined in discounted terms over an infinite time horizon.

$$(1.17) \qquad \pi_0 = \int_{t=0}^{t=\infty} (\bar{p}Kx - C)e^{-\delta t}\,dt.$$

When (1.17) is maximized subject to the constraint that $\frac{dX}{dt} = 0$, we get the same solution for the profit-maximizing biomass as in (1.15). This result follows irrespective of the value of the interest rate -- a sustained yield restriction implies that there is no trade-off between present and future production, and thus present versus future profits. In other words, maximizing profits for a single period is consistent with maximizing the present value of discounted profits over a infinite time horizon. Once the assumption of a sustained yield restriction is relaxed, i.e., $\frac{dX}{dt} \neq 0$, then industry output is defined as,

$$(1.18) \qquad Kx = aX - bX^2 - \frac{dX}{dt},$$

and maximizing (1.17) under these circumstances will not yield the same stationary biomass unless the interest rate, δ, is equal to zero. The theorem that the sole owner will always operate with a biomass greater than that consistent with maximum sustainable yield no longer holds: what stationary solution obtains depends upon δ. If the latter is high enough, it may be perfectly rational to deplete the resource. Dynamic maximization in the present context was more thoroughly developed by Plourde (25). Using the variable yield function implicit in (1.18) and assuming zero production costs, the problem is reduced to one of maximizing the welfare functional:

$$(1.19) \qquad \max \int_0^\infty u(C_t)e^{-\delta t}\,dt.$$

Plourde's basic results follow directly from the time preference framework of his model; namely, that maximum sustainable yield programs are optimal only when the discount rate is zero; that when $\delta > 0$, the steady-state biomass X^*, and corresponding steady-state yield (consumption) level C^*, are smaller; that when the latter holds, there exists an optimum time path to C^*, X^*; and finally, that the introduction of positive and high production costs could -- even for a high value of δ -- change the social decision from one of depletion of the resource to non-exploitation.

In conclusion, it can be pointed out that while most of the theoretical literature has been dominated by 'static' considerations related to externalities generated under rather rigid conditions $\frac{dX}{dt} = 0$, a linearly homogeneous production function with respect to the number of vessels, etc. , it appears that the relaxation of some of these assumptions has paved the way for a more general, dynamic analysis -- and it is in this area that new theoretical developments may occur. For example, more complicated externalities may be introduced by positing certain relationships between species or fisheries, so that output per vessel in fishery i may be a function of the amount of effort exerted upon fishery j; at the same time, certain types of suboptimization problems -- such as the interallocation of capital between fishing grounds holding the total level of capital in the marine resource sector fixed -- could also be examined. On the other hand, empirical estimation of parameters within the boundaries of the conventional theory would also reflect a significant contribution, particularly with respect to possible policy implications.

3. Initial Framework[8]

The present study fits into both categories, i.e., it attempts to expand upon certain undeveloped components of the conventional theory and estimate parameters implicit in the expanded analysis. However, we will follow the 'classic' approach by not using the variable yield function-- (i.e., $Kx=f(X) - \frac{dX}{dt}$) and thus will ignore all of the dynamic ramifications inherent in the framework.[9] The form of the production function prior to the attainment of maximum sustainable yield may take either the form of the traditional linearly homogeneous function or one with non-constant returns with respect to the number of boats. Thus, the

[8]John Cumberland has pointed out that this study implicitly assumes that the present level of ecological balance will be maintained. However, it is possible and perhaps even likely for some species that pollution will disrupt the state of environmental balance. There are two ways in which an hypothesized ecological disruption can be handled within the framework of this research. First, estimates of maximum sustainable yield could be reduced to reflect the impact of environmental damage upon the sustainable harvest. Secondly, the effect on the demand for particular species could be measured by negative time trends to reflect changes in consumers' taste. Needless to say, the data required to analyze this type of problem are woefully inadequate. The important point is that the conceptual framework developed here does not require modification.

[9]A supplementary result of assuming $\frac{dX}{dt} = 0$ is that under optimal conditions the biomass never becomes depleted. Thus, 'conservation' is explicitly assumed to be optimal, i.e., preferred.

relationship between yield and effort, or K, can be

$$(1.20) \quad Kx = \alpha K - \beta K^2,$$

for the l.h.p.f., or,

$$(1.21) \quad Kx = \alpha K^{\mu} - \beta K^{2\mu} \quad 0 < \mu < 1,$$ [10]

for the n.c.r.p.f. However, once the level of output reaches a maximum, let us assume that the long-run supply curve becomes perfectly inelastic (as opposed to backward-bending), so that either of the specified equilibrium production functions are valid until the yield is equal to MSY and thereafter output is maintained at that level irrespective of price. This is illustrated in Figure (1.4). For some fisheries, the assumption of a completely inelastic as opposed to backward-bending supply curve is quite reasonable.[11] For other fisheries where the theoretically specified backward sloping function[12] is a real possibility, the assumption of

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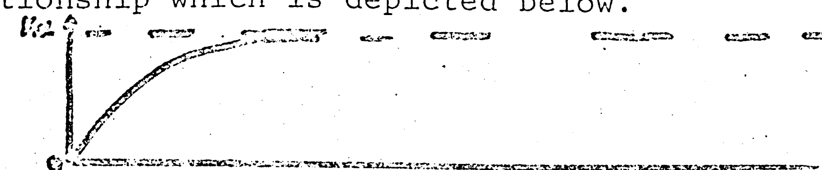
[10] A variant of this was developed by E. Carlson. His function is $Kx = (1-(1-t)^K)X$, where K, X, and t are the number of boats, the biomass, and the percentage reduction in the biomass caused by the introduction of the first boat respectively.

[11] For example, the Shrimp fishery has a yield effort relationship which is depicted below.



This implies an inelastic supply curve once maximum yield is reached. In addition, in Pella and Tomlinson's work (24), a generalized growth function is specified: $Kx = aX - bX^m$. As $m \to 0$, the implied supply function approaches perfect inelasticity.

[12] See the study by Copes (8), which describes the possibility of a backward sloping supply function.

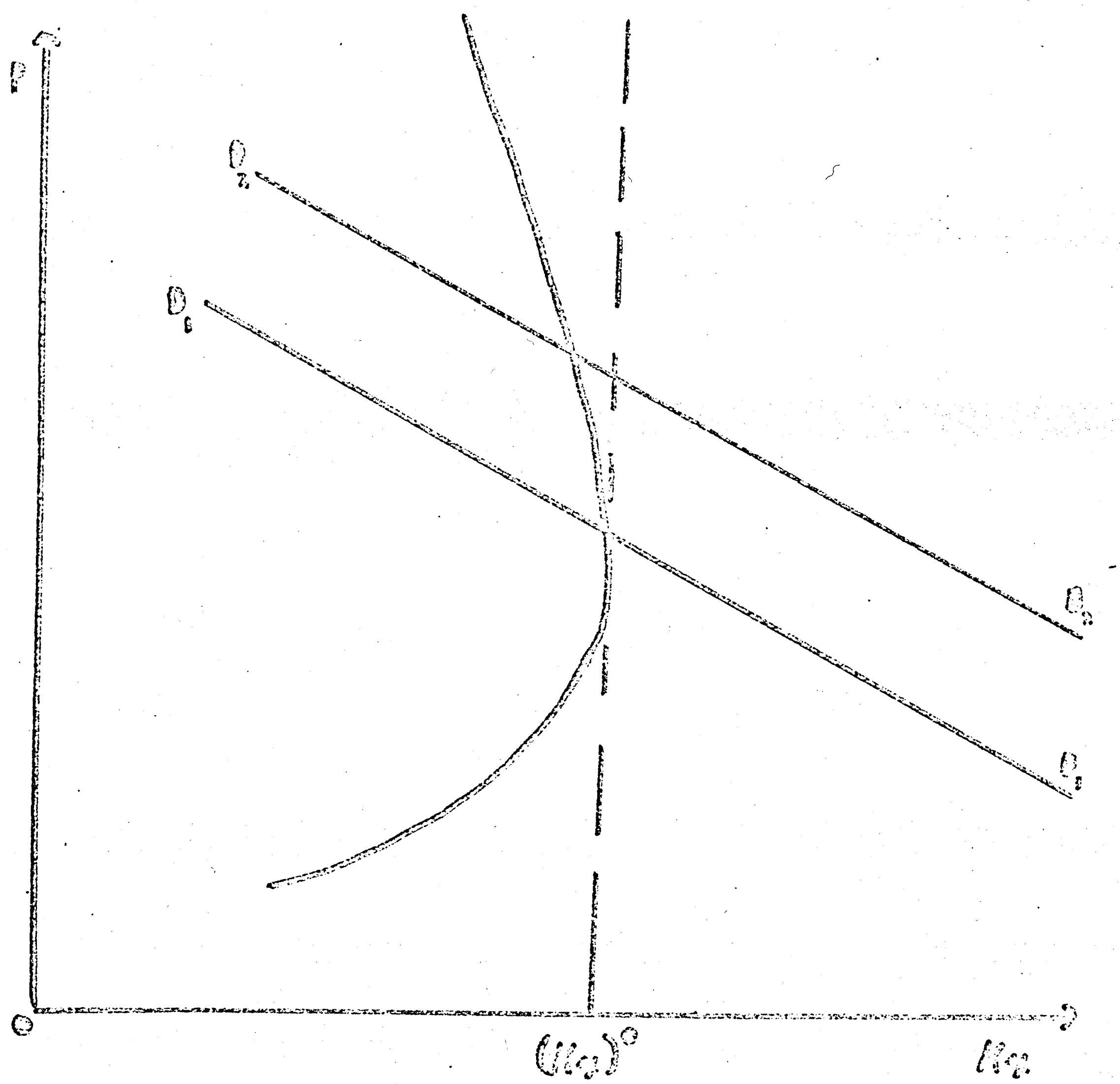


FIGURE 1.4

perfect inelasticity can still, under certain institutional arrangements, be a valid one: the imposition of regulations (for some intensely exploited species) which limit the annual catch to maximum sustainable yield effectively implies a zero elasticity of supply schedule.[13] However, even when specified prohibitions are not imposed, the perfectly inelastic supply function is not an altogether inaccurate approximation of the true supply function.[14]

Thus far, little has been modified with respect to the conventional framework. Two assumptions, though, that do change that framework in more definitive terms are, in essence logical extensions of the usual analysis. First, on the demand side, there is the more generalized theoretical structure in which the demand for a given species i is a function of the price of i, income, <u>and the prices of all other species</u> A detailed discussion of this aspect is given in chapter two. Secondly, on the supply side, there is again a more generalized extension. Suppose that the fishing sector is comprised of

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[13]The halibut fishery in the Pacific Northeast is a good example of regulation at MSY.

[14]Simulations of the production function in the text showed that many of the fisheries exhibited very slowly backward-bending supply schedules. If a production function exhibiting non-constant returns with respect to the number of vessels were used, this would *a fortiori* make the assumption of perfect inelasticity at and after MSY an accurate depiction of the industry supply curve. In fact, some of the production functions of the form developed by Carlson implied perfect inelasticity as a limiting value.

n subsectors. We may then dichotomize the n subsectors of the fishing industry on the basis of proximity to the absolute biological constraint, i.e., maximum sustainable yield. The first component will include those species which are at or near MSY. A sizable portion of the industry is in this category. The second component is the obverse of the first; it is comprised either of those species which are not close to maximum sustainable yield -- the underutilized species -- or those species for which artificial techniques of cultivation have been developed. This second component will be referred to as the unconstrained species. Accordingly, we will assume that the latter have perfectly elastic supply functions at some given level of prices. Thus, the set of all marine resources is analytically subdivided into two mutually exclusive subsets: the constrained set and the unconstrained set.

The problem upon which some attention will be focused in this research work may be initially illustrated within a partial framework by reference to Figure (1.4). Assume that the initial demand curve is given by D_1D_1. Assume further that profits are zero and all firms are in long-run equilibrium. With an increase in demand to say D_2D_2, rents are generated and additional capital and labor resources are drawn into that subsector, profits are bid away and -- in the new long-run equilibrium position -- output will not have increased. The social marginal product of additional inputs is equal to zero.

The primary objective in this study will be to translate this phenomenon into general equilibrium terms. That is, suppose, within the context of a forecast of marine resource consumption -- predicated upon perfectly elastic supplies of all species at a given level of prices -- we arrive at a combination which has as a component a technically unattainable set. In other words, the forecast includes a set -- the constrained set -- which we know, *a priori*, is not feasible because all of the elements exceed maximum sustainable yield. One of the aims of our analysis is to determine the change in prices -- given that the level of output reaches the point at which the supply function is perfectly inelastic. A second objective will be to find an alternative combination which includes MSY of the constrained set but which also includes more of the unconstrained set such that in some sense society will be as well off as at the originally projected, but unattainable bundle. Put differently, our intention is to derive a combination which compensates society for the loss in welfare imposed by the resource constraint at MSY. Policy implications will then be examined in the light of the significance of our estimates.

It is important to note that this is neither an optimization nor, for that matter, a suboptimization problem. In one sense it is an attempt to draw certain conclusions from two sources: (1) estimated demand parameters, and (2) a modicum of information related to the biotechnological aspects of the industry. Implicit in the analysis is the perhaps the heroic assumption that capital and labor resources needed to produce the solution generated by the market are transformable and sufficiently large to produce the "alternative combination." To that extent, the latter could serve as a minimum goal toward which a policy specifically designed for the redistribution of effort among subsectors could be directed. However, the policy prescriptions inferred from this type of framework cannot in any meaningful way be regarded collectively as a substitute for the type of analysis in which the marginal value product of factors is equalized between fisheries. Thus, policy implications must be applied with caution and qualification. On the other hand, the usefulness of this point of view is enhanced when maximum sustainable yield is included as a part of any solution. That is, since marginal cost is infinite when output is equal to maximum sustainable yield, it follows that in any given optimization scheme, maximum yield will never be a component of the optimal solution.[15]

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[15] Actually, as demand increases over time, the level of output at which marginal cost is equal to price approaches maximum sustainable yield. If we consider marginal cost pricing in some future period, the difference in output between marginal cost pricing and MSY is of the second order of smalls and thus the categorization of "second best" tends to under-estimate the point of view of the analysis.

CHAPTER II

METHODOLOGY: THE ECONOMIC MODEL

1. Introduction

Thus far, the thrust of our analysis has been centered upon the common property nature of the resource and the implications the latter has posed relative to the allocation of resources. Complementary to this problem and of extreme importance to a full theoretical development is the methodological foundation underlying the demand related phenomena of this study, i.e., the projection of consumption of marine resources over time and the estimation of own and cross price partial derivatives designed to measure the impact of the resource constraint upon relative prices. It is the purpose of this chapter to outline that methodology, accompanied by an exposition of the *a priori* expectations with respect to the results of the empirical research discussed in the next two chapters. Accordingly, section two presents the entire demand model along with some initial remarks which highlight some of the general points of interest of the study. Section three integrates the model into a framework in which possible policy implications can be discussed.

2. The Demand Model

Figure (2.1) illustrates the basic problem and serves to introduce the procedure that will be followed. Let us assume that there are only two species of fish, x and y. Figure (2.1) represents a partial community indifference

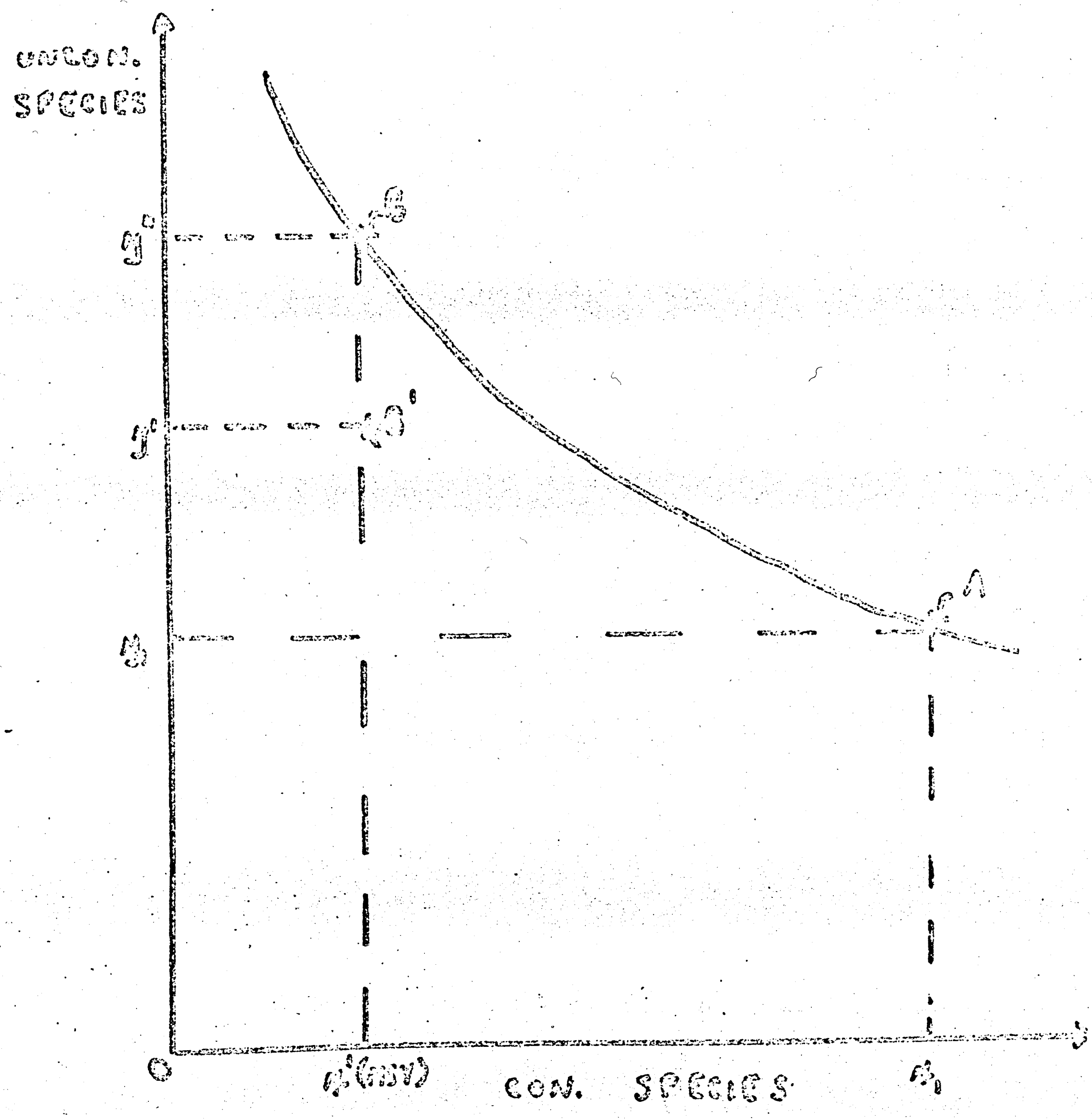

FIGURE 2.1

curve for the two species for a given year in the future, derived from some exogenous projection of aggregate (or per capita) income. Assume that at some set of relative prices a forecast of consumption would yield the combination indicated by point A: ox_1 of x and oy_1 of y. However, bundle A is unattainable because ox_1 of x is beyond maximum sustainable yield; we can, though, obtain a combination which includes the technically feasible quantity of x -- given by ox^1 (equal to MSY) -- and which also includes an incremental amount of y such that society will be as well off as at the originally projected, but unattainable bundle. This is given by point B in Figure (2.1). In other words, the original forecast (point A) was predicated upon perfectly elastic supplies of the two species of fish. We may refer to x as the constrained species and y as the unconstrained species. The essential proposition of this paper is that the equilibrium solution generated by the competitive model will yield a position which is inferior to or below point B and that this solution involves an excessive amount of capital and labor in the production of the constrained species. In other words, even after the market makes all price adjustments for the constrained species and quantity adjustments for the unconstrained species, society will nonetheless be worse off than at the originally projected combination.[1] Given that there

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[1]Put differently, we have marginal cost pricing for the unconstrained species, but non-marginal cost pricing for the

are input redundancies in the production of x, a policy aimed at the redistribution of effort could use point B as a minimum target for increasing the level of output for species y.[2] At any rate, the dollar difference between point B and some hypothetical market clearing point, say, $B^{1.}$, measures the welfare loss to society incurred as a result of the combination of the biological constraint and the modified free market mechanism.[3] This welfare loss is a minimal measure under the assumption that economic resources could be reallocated such that the combination indicated by point B would be produced.

Implicit, then, is the general equilibrium nature of our analysis: each subsector of the fishing industry will be viewed within an interdependent framework where the consumption of one species is functionally related to the prices of all species and income.[4] Assume, for example,

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constrained species (MC ∞ here). Therefore, a better solution can be effected that will increase the level of output of the unconstrained subsectors without reducing the level of output in the constrained subsectors.

[2]This of course assumes a closed economy. This assumption will be relaxed in chapter five.

[3]By the "modified free market mechanism" we mean the imposition of regulations in those instances in which the supply curve is backward bending which limit the level of output per unit of time without any concomitant restriction on the entry of new capital.

[4]Two features of this type of framework should be mentioned. First, this is only semi-Walrasian system: the impact of the prices of the non-fish category is assumed so

that there are n species of which i fall into the constrained category. Given that the market for each of those i species clears at maximum sustainable yield and given the assumption of perfect supply elasticity of the (n-i) unconstrained species, it is possible to obtain i price changes for the constrained set, (n-i) quantity adjustments for the complementary set, and a comparison of the latter to the quantity adjustments developed from a constant utility locus.

The typical price partial, $\frac{\partial x_i}{\partial p_j}$, may be derived as follows. Assume the existence of a utility function coupled with a budget constraint, such that,

$$(2.1) \quad u = u(q_i, q_2, \ldots, q_n) - \lambda\,(\Sigma p_i q_i - y)$$

where q_i, p_i, and y are quantity and price of commodity i and income respectively. Differentiating (2.1) with respect to q and λ, setting equal to zero, we get,

$$(2.2) \quad u_i - \lambda p_i = 0, \quad i = 1, \ldots, n$$

$$(2.3) \quad \Sigma p_i q_i - y = 0$$

Differentiating (2.2) and (2.3) with respect to some given price, say p_1, we obtain the matrix of second partials and cross quantity derivatives of the utility function bordered by prices, i.e.,

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relatively negligible that it is ignored. Secondly, it should be borne in mind that the general equilibrium structure is continuously changing and that we are dealing with linearized estimates that approximate the true structure only within a neighborhood of points, and thus, by definition, are not valid for an entire spectrum of prices.

$$(2.4)\quad \begin{pmatrix} u_{ii} & \cdots\cdots\cdots & u_{in} & -p_i \\ \vdots & & & \\ \vdots & & & \\ u_{ni} & \cdots\cdots\cdots & u_{nn} & -p_n \\ -p_i & \cdots\cdots\cdots & -p_n & o \end{pmatrix}$$

The $\frac{\partial x_i}{\partial p_1}$ is then given by;

$$(2.5)\quad \frac{\partial x_i}{\partial p_1} = \lambda\, u_{i1}^{-1} - x_1 \frac{\partial x_i}{\partial y},$$

where u_{i1}^{-1} is the i, 1th element of the inverse of (2.4), and $-\frac{\partial x_i}{\partial y}$ is the i, n+1 element of the inverse of (2.4). The latter is commonly referred to as the income effect, while the first expression on the right hand side of (2.5) is called the substitution effect.

The constant utility locus of quantity adjustments is derived from own and cross price partials which consist only of substitution effects; on the other hand, market changes include both substitution and income effects. A major component of our research will involve the estimation of all own and cross price partials with a consequent breakdown as in (2.5). Prerequisite to this aspect, however, is a forecast of consumption, and it is the latter which constitutes another component of this study. This section, then, is subdivided into two basic parts: (1) one pertaining to the forecast, and (2) a subsection discussing the formulation of the price derivatives.

A. The Forecast

The technique used in formulating the projections makes use of both time series and cross-sectional data and is similar to a method employed by Powell (26). Forecasts are derived from a set of linear expenditure functions, in which the amount spent on commodity i depends upon the prices of all commodities, aggregate expenditures -- a proxy variable for income -- and a time trend. This may be specified as follows:

$$(2.6) \quad v_{it} = \sum_{j=1}^{k} a_{ij}p_{jt} + b_i m_t + c_i t + e_{it} \quad (i = 1,\ldots,k),$$

where v_{it} and m_t are per capita nominal expenditures on the i^{th} commodity and per capita aggregate expenditures in period t respectively, t is time (a proxy for changes in consumers' taste), and e_{it} is an error term. The coefficients a_{ij} and b_i have the following meaning respectively:

$$(2.7) \quad a_{ij} = p_i\frac{\partial x_i}{\partial p_j} + \delta_{ij}x_i = p_i(k_{ij} - x_j\frac{\partial x_i}{\partial y}) + \delta_{ij}x_i,$$

$$(2.8) \quad b_i = p_i\frac{\partial x_i}{\partial y}$$

where δ_{ij}=1 when i=j, and 0 when i≠j, and k_{ij} and $-x_j\frac{\partial x_i}{\partial y}$ are respectively the substitution effect and the income effect of the i^{th} commodity. In this system, (2.7) may be estimated as a parameter at sample mean price and quantity for a given commodity. Because of the use of aggregate expenditures -- as opposed to aggregate income -- we have the identity: $\sum_{i=1}^{k} v_{it} \equiv m_t$. Given this, another set of identities can be obtained:

(2.9) $\sum_{i=1}^{k} b_i \equiv 1$

(2.10) $\sum_{i=1}^{k} \sum_{j=1}^{k} a_{ij} p_j \equiv 0$

(2.11) $\sum_{i=1}^{k} c_i \equiv 0$ [5]

The basic assumption underlying Powell's technique is that the relationship between commodities in the utility function is additive; so that,

$$(2.12) \quad U = U(x_1) + U(x_2) + \ldots\ldots + U(x_k).$$

Thus, the marginal utility of any commodity i is independent of the level of consumption of any commodity j, for $i \neq j$. There is no test of this assumption, other than the use of fairly aggregative consumer categories which make the specification in (2.12) intuitively plausible. The inclusion of fish as a separate commodity does not adhere to this rule in the sense that expenditures on fish do not comprise a substantial proportion of the consumer's budget and that certainly there is some substitutability in the utility function between fish and some other food product, say, meat.

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[5] These three identities follow from the definition of 'income' as the sum of expenditures. (2.9) is given by the fact that the sum of marginal expenditures is equal to the increase in total expenditures. (2.10) requires some further explanation. First, it follows that $\sum_i \sum_j a_{ij} p_j \equiv \sum_j \sum_i a_{ij} p_j \equiv \sum_j p_j \sum_i a_{ij}$. However, $\sum_i a_{ij} = \sum_i p_i \frac{\partial x_i}{\partial p_i} + \delta_{ij} x_i$. It is also true that when $(\sum p_i x_i - y) = 0$, $\sum_i p_i \frac{\partial x_j}{\partial p_j} = -x_j$. Since $\delta_{ij} = 1$ when $i=j$, $\sum_i a_{ij}$ reduces to zero, and thus expression (2.10) is also identical to zero. Given that (2.9) and (2.10) are identical to one and zero respectively, it follows that $\sum_{i=1}^{k} c_i \equiv 0$, so that $\sum_{i=1}^{k} v_{it} \equiv m_t$ is satisfied.

However, we are not concluding that there is no substitutability or no complementary between any given food category and fish; what we are implying is that any substitutability is balanced by complementarity so that there is <u>net</u> additivity or independence in the utility function between fish on the one hand and the category 'all other foods' on the other. Nonetheless, an implicit test of the additivity assumption within this context can be devised.[6]

It has been shown that, given the assumption of separability, all of the own and cross price derivatives can be specified in terms of income derivatives. Frisch (13), Strotz (34), Houthakker (18), and Johansen (19) have each demonstrated that under this form of the utility function if all income derivatives and one price derivative are known then all price derivatives can be obtained. Consequently, the price partials may be specified as follows:

$$(2.13) \quad \frac{\partial x_i}{\partial p_j} = -\frac{\partial x_i}{\partial y}\left(x_j + \gamma \frac{-\partial x_j}{\partial y}\right), \; i \neq j$$

$$(2.14) \quad \frac{\partial x_i}{\partial p_i} = \frac{\partial x_i}{\partial y}\left(-\frac{\gamma}{p_i} + \frac{\gamma \partial x_i}{\partial y}\right) - x_i \frac{\partial x_i}{\partial y}, \text{[7]}$$

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[6] See Appendix A.

[7] These results can easily be demonstrated. Let us represent the matrix of the form given in (2.4) (in matrix notation) as,

$$(7.1)' \quad \begin{pmatrix} U & -p \\ -p' & 0 \end{pmatrix}$$

where $\frac{\partial x_i}{\partial y}$ is as defined before and γ has the meaning,

$$(2.15) \quad \gamma = -\lambda \,/\frac{\partial \lambda}{\partial y} ,$$

where λ is the marginal utility of income. Given the constraint that $\sum_i p_i \frac{\partial x_i}{\partial y} = 1$, it is possible to solve for γ using (i-1) independent estimates of the income coefficients and one independent value of $\frac{\partial x_i}{\partial p_j}$. Powell, however, estimates all income derivatives and γ endogenously; once these parameters are found all of the price partials can be deduced. However, we are not interested in the price partials between the all fish category and the other [aggregate] consumer commodities per se. Rather, it is the income coefficient, or more precisely the expenditure parameter b_i, the

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where U is a diagonal matrix (because of the additivity assumption) with typical element equal to u_{ii}. In the process of inverting (7.1) we can make the following transformation (for ease of illustration): $-p'U^{-1}p=1$. Thus, the inverse of (7.1)' becomes,

$$(7.2)' \quad \begin{pmatrix} U^{-1}+U^{-1}PP'U^{-1} & U^{-1}p \\ p'U^{-1} & 1 \end{pmatrix}$$

When the matrix $(U^{-1}+U^{-1}pp'U^{-1})$ is multiplied by λ, the matrix of substitution effects is formed. Since $-U^{-1}p$ is equal to the vector of income derivatives, and since U^{-1} is a diagonal matrix with typical element $1/u_{ii}$, it follows that the $\frac{\partial x_i}{\partial y}$ is equal to $-p_i/u_{ii}$. If all of the income derivatives are known, then all of the elements of U^{-1} can be found. Given the knowledge of one price derivative, λ can also be obtained, and, as a result, all of the own and cross price derivatives can be found.

parameter on time c_i, and the estimated value $\hat{\gamma}$ which are critical in this part of our research. The first two estimates provide all the necessary information for the forecast of fish consumption, while the last is essential in order to obtain all the price partials between species of fish.

Given the additivity assumption about the utility function given in (2.12), we have the following relationships within the system of linear expenditure equations:

$$(2.16) \quad a_{ij} = \gamma b_i b_j/\bar{p}_j - b_i \bar{x}_j \quad (i \neq j)$$

Because of the budget constraint -- the sum of expenditures on individual commodities are identical to total expenditures -- another identity holds, namely:

$$(2.17) \quad \sum_{i=1}^{k} a_{ij} \equiv 0 \qquad (j=1,\ldots\ldots,k)$$

Given (2.17) and (2.16), it then follows that,

$$(2.18) \quad a_{ii} = (b_i - 1)(\gamma b_i/\bar{p}_i - \bar{x}_i) \quad (i=1,\ldots\ldots,k)$$

Linearization of the price partials in this system is imposed at sample mean quantities and prices, $\bar{x}_j(\bar{x}_i)$ and $\bar{p}_j$ $(\bar{p}_i)$ respectively. From (2.16) and (2.18), we may derive an alternative expression for (2.6)[8]:

$$(2.19) \quad v_{it} = p_{it}\bar{x}_i + \gamma z_{it} + b_i u_t + c_i t + e_{it} ,$$

where z_{it} and u_t are defined as:

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[8] For further explanation of this derivation, see Powell (26).

$$(2.20) \quad z_{it} = b_i \sum_{j=1}^{k} (b_j (p_{jt}/\bar{p}_j - p_{it}/\bar{p}_i)) ,$$

$$(2.21) \quad u_t = m_t - \sum_{j=1}^{k} p_{jt} \bar{x}_j$$

(2.19) can finally be changed to:

$$(2.22) \quad y_{it} = b_i u_t + c_i t + e_{it} \qquad (i=1,\ldots\ldots,k)$$

in which

$$(2.23) \quad y_{it} = q_{it} - \gamma z_{it} \quad (i=1,\ldots\ldots,k)$$

and

$$(2.24) \quad q_{it} = v_{it} - p_{it} \bar{x}_i \quad (i=1,\ldots\ldots,k)$$

Thus, the original expenditure functions are transformed into relationships in which exogenous variables only appear on the right hand side of (2.6). In other words, since u_t is a function of m_t and p_{jt}, and since neither one of these variables is explained within this system, the set of linear expenditure functions is reduced to a set of equations with completely exogenous independent variables. The economic interpretation of the transformed variables may be concisely clarified. The left hand side of (2.22) can be viewed as the difference between 'transient' purchases of the i^{th} commodity, q_{it}, and those purchases resulting from substitution effects, γz_{it}. The right hand side of (2.22) is comprised first of a variable, u_t, representing the difference between money income and expenditure upon the consumption of certain 'normal' quantities $\bar{x}_j$, and secondly, of a time trend intended to represent changes in consumers' taste.[9]

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[9]Powell (26), p. 663.

The method of estimation involves an iterative technique in which prior restrictions on the system give -- with one exception -- maximum likelihood estimators and the same estimates as would be obtained using two-stage least squares. In order to derive the vector of dependent observations on the left hand side of (2.22) one must first have an initial set of $\{b_i\}$ so that a corresponding observation vector $\{z_{it}\}$ for each i may be computed as well as a prior value for γ. Powell solves for the latter by using a technique developed by Leser.[10] Given that γ appears in all k equations, the criterion chosen is that which will minimize the grand total sum of squares; i.e.,

$$(2.25) \qquad \min \sum_{i=1}^{k} \sum_{t} (q_{it} - \hat{q}_{it})^2$$

Within this context, γ, as well as the other 2k parameters may be simultaneously estimated by differentiating (2.25) with respect to each of the parameters, setting equal to zero, and solving. Thus, we have

$$(2.26) \qquad \hat{\Psi} = Z^{-1}\phi$$

where (2.26) follows from the first-order conditions for a minimum.

In the above system, $\hat{\Psi}$ is a (2k+1)x1 vector, and is equal to,

$$(2.27) \qquad \hat{\Psi} = (\hat{\gamma}\ \hat{b}_1\hat{c}_1\hat{b}_2\hat{c}_2\ldots\ldots\hat{b}_k\hat{c}_k)',$$

is also a (2k+1)x1 vector,

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[10] See "Demand Functions for Nine Commodity Groups in Australia," by C.E.V. Leser in Australian Journal of Statistics, 2, 1960, pp. 102-13.

$$(2.28)\quad \phi=\left(\sum_{i}\sum_{t} z_{it}q_{it},\ \sum_t u_t q_{it},\ \sum_t t q_{it},\ \sum_t u_t q_{zt},\ \sum_t t q_{zt},\ \ldots\ldots,\ \sum_t u_t q_{kt},\ \sum_t t q_{kt}\right)$$

Z is a matrix of order (2k+1) x (2k+1) and is given by

$$(2.29)\quad Z = \left(\begin{array}{c|cccc} \sum\limits_{i}\sum\limits_{t} z_{it}^{2} & & H' & & \\ \hline & \Omega & 0 & \cdots & 0 \\ & 0 & \Omega & & \vdots \\ H & \vdots & & \ddots & \vdots \\ & 0 & \cdots & \cdots & \Omega \end{array}\right)$$

The different components of Z include H, a 2kx1 vector, Ω , a 2x2 submatrix, 0, a 2x2 null submatrix, and $\sum\limits_{i}\sum\limits_{t} z_{it}^{2}$ is a scalar. H and Ω have the following meaning:

$$(2.30)\quad H=\left(\sum_t z_{it}u_t,\ \sum_t t z_{it},\ \sum_t z_{zt}u_t,\ \sum_t t z_{zt},\ \ldots\ldots,\ \sum_t z_{kt}u_t,\ \sum_t t z_{kt}\right)'$$

$$(2.31)\quad \Omega = \begin{pmatrix} \sum\limits_t u_t = & \sum\limits_t t u_t \\ \sum\limits_t t u_t & \sum\limits_t t^2 \end{pmatrix}$$

For an initial set of $\{b_i\}$ all of the z_{it}'s can be found and, correspondingly, once an estimate of the z_{it}'s is obtained, the vectors H and ϕ can be formed, and $\hat{\Psi}$ can be estimated. The new values of the $\{b_i\}$ on the left hand side of (2.26) are then substituted into the right hand side of (2.26) to form another set of vectors, H, ϕ, and $\hat{\Psi}$ is re-estimated. This iterative procedure is continued until convergence is attained, i.e., until the $\{b_i\}$ estimated in $\hat{\psi}$ are equal to the $\{b_i\}$used in deriving the z_{it}'s that are found in H and ϕ.[11] The components of Ω are completely exogenous, and, as a result, the elements of Ω do not change from iteration to iteration. In addition, the estimates obtained after convergence are at least partially consistent with the Aitken-Zellner two-stage least squares estimates.[12]

After convergence has been attained, we will have an estimate of the expenditure coefficient for fish $\hat{b}_F$, an estimate of γ, $\hat{\gamma}$, and a parameter on time, $\hat{c}_F$. From the point of view of the forecast, $\hat{\gamma}$, is unimportant. In fact, given the transformations made within the system, the term $\hat{\gamma} z_{it}$ disappears within a forecasting context: since the projection will be made at mean price levels, $\bar{P}_j$, the term z_{it} is evaluated at $P_{jt} = \bar{P}_j$, and is thus equal to zero. We would expect the sign of $\hat{b}_F$ to be positive but in all likelihood not significantly different from zero. The inclusion of the time variable requires some further explanation. The

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[11] In the actual estimation process to be described in chapter 3, the condition for convergence is reformulated into an equivalent condition concerning $\hat{\gamma}$. The procedure described there is identical to the one theoretically specified here, but is computationally less difficult. In addition, the estimation procedure ensures that the identities, $\sum_i b_i = 1$, $\sum_i c_i = 0$, are maintained. For details, see section 2 of chapter three.

[12] One problem, however, is that the conditional distribution for e_{it}, given all of the other (k-1) contemporaneous error terms from the statistically fitted equations, does not exist.

time series estimated expenditure parameter will be used in conjunction with a series of cross-sectionally derived measures; the addition of the time variable serves to extract trends from the equation so as to obtain 'pure' or long-run expenditure partials, comparable to cross-sectional estimates in a time series framework. Others who have used a modified version of the Powell technique have found time trends an important demand shifter.[13] At the same time, a high degree of long-run intercorrelation between "t" and "u_t" will not hamper the efficacy of the equation as a forecasting device.[14]

Given some exogenous projection of aggregate (per capita) expenditures we then can derive an estimate of u_t:

$$(2.32) \qquad \hat{u}_t = m_t - \sum_{j=1}^{k} \bar{p}_j \bar{x}_j$$

Thus, the forecasting equation would be specified as,

$$(2.33) \qquad \hat{v}_{it} = \bar{p}_i \bar{x}_i + \hat{b}_f \hat{u}_t + \hat{c}_f t.$$

We would accordingly have a projected value for real per capita consumer expenditures for fish for a year or set of years into the future. This would complete the time series component of the empirical research. However, the information

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[13] See, for example, "A Multi-Sectoral Analysis of Consumer Demand in the Post-War Period," by Alan A. Powell, Tran Van Hoa, and R. H. Wilson, in The Southern Economic Journal, October, 1968, pp. 109-120. The only difference in that article was the attempted incorporation of non-linear responses to changes in income.

[14] J. Johnston, Econometric Methods, chapter eight.

obtained in this analysis will complement the cross-sectional parameters in two important ways. First, the parameter $\hat{b}_F$ will serve as a control total in 'distributing' expected expenditures for fish across species. In other words, individual species expenditure coefficients, cross-sectionally estimated, will be modified so that the sum of these individual coefficients equals the parameter $\hat{b}_F$; the modified coefficients will then serve as the basis for allocating the predicted level of total fish expenditures among species. Thus, in this first instance not only will the time series analysis complement the cross-sectional study, but the latter will play a prominent role in the time-series oriented projections as well. Secondly, $\hat{\gamma}$ -- derived after convergence of the iterative technique discussed above -- will be utilized as a component of the own and cross price partial derivatives which will be estimated in the cross-sectional study.

B. The Cross-Sectional Study and the Formulation of the Price Derivatives

The second major part of the empirical research stems from a recent household survey across regions.[15] The purpose is to derive certain bits of independent information to be inserted into the general equilibrium system in which a set of estimates totally consistent within that framework

[15] A household survey was conducted by the National Marine Fisheries Service in 1969.

can be obtained. For each species there will be an estimating equation of the form:

$$(2.34)\quad v_{il} = \Sigma a_{ij}p_{jl} + b_i m_l + \sum_{j=1}^{m} c_j x_{jl} + e_{il}$$

In (2.34), v_{il} is per capita expenditure for the i^{th} species by the l^{th} household (or group of households), the a_{ij} have the same meaning as in (2.7), m_l is annual per capita income, and the 'x_{jl}' represent certain socio-economic characteristics. The latter are included so as to attempt to abstract from the impact of differences in taste among households upon the regression coefficients of the economic variables. Such characteristics as family size, race, religion, regional taste factors, etc., can all be handled either by a set of dummy variables -- when observations are on a household level -- or by continuous variables (i.e., proportion of a particular race or religion within a group of households) on a more aggregated basis. After these socio-economic features have been accounted for, and a set of price and income coefficients are derived, we will integrate some of the cross-sectional results with those of the time series analysis. Given a set of n income coefficients -- one for each species -- from the cross-sectional study, consistency between these and the expenditure coefficient for all fish can be attained in the following manner. Assume that $\hat{\hat{b}}_i$ represents the unrestricted income coefficient of the i^{th} species estimated in (2.34). Then, the income coefficients will be modified according to the rule,

$$(2.35)\quad \hat{b}_i^* = (\hat{b}_i / \sum_{i=1}^{n} \hat{b}_i)\, \hat{b}_f,$$

where $\hat{b}_i^*$ is the income coefficient of the i^{th} species consistent in a general equilibirum context, and $\hat{b}_F$ is as defined above. While this method may appear arbitrary, if the sum of the unrestricted cross-sectional income coefficients comes reasonably close to the time series control total, the method used to distribute the residuals will be of only minor importance.[16] Thus, the forecast of expenditures for all fish given in (2.33) will be subdivided between species on the basis of the set of $\{b_i^*\}$ and on the basis of actual mean expenditures for the various species (the first expression of the right hand side of (2.33)).[17] Accordinlgy, there is consistency in two respects: (1) the sum of the modified expenditure coefficients are consistent with the constraint imposed in equation (2.9), namely that $\sum_{i=1}^{k} b_i = 1$;

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[16] One reason why we might expect the sume of the cross-sectional coefficients to be very close to the time series control total is that the purpose of the inclusion of time as a variable in the time series equations was to obtain long-run parameters on aggregate expenditures. The cross-sectional estimates, on the other hand, also reflect long-run income estimates.

[17] This requires further explanation. The first expression on the right hand side of (2.33) is $\bar{p}_i\bar{x}_i$. However, $\bar{x}_i$ is a quantity index equal to $\bar{v}_i/\bar{p}_i$. Therefore, $\bar{p}_i\bar{x}_i=\bar{v}_i$, i.e., mean fish expenditures. On the other hand, $\bar{v}_i$ can be broken down according to species.

(2) the projection for all fish expenditures is equal to the sum of forecasted consumer expenditures for each species.

The second component of the cross-sectional analysis involves a set of estimated price coefficients. In particular, what is needed is a set of n(n-1)/2 reliable price partials. The only constraint in selecting an element of this set is the condition that once $\frac{\partial x_i}{\partial p_j}$ is selected for $i \neq j$, $\frac{\partial x_j}{\partial p_i}$ cannot be chosen. This is true for some given i and j. This condition, the number of elements needed in the initial price set, and the method of obtaining the entire array of price partial derivatives follow from the tenets of utility maximization. More specifically, given some generalized, highly unrestrictive assumptions about the utility function[18] it can be shown that with the set of modified income coefficients as well as the n(n-1)/2 reliable price derivatives that the entire set of nxn price partials can be estimated.

Assume that we already have the estimated set of price coefficients $\{ a_{ij} \}$ and the set of n expenditure derivatives $\{ b_i^* \}$. Further assume that there are n species of fish and k-1 other [aggregated] commodities. Given the assumption of additivity introduced before, we can postulate the partitioned matrix of the first partial derivatives of the marginal utilities with respect to quantities, bordered

[18] Unrestrictive assumptions only with respect to one species of seafood versus another species -- not with respect to seafood vis a vis other commodities.

by prices, as

(2.36)

$$\begin{pmatrix} F & \Phi & -P_F \\ \Phi' & G & -P_G \\ -P_F' & -P_G' & 0 \end{pmatrix}$$

This is the same type of matrix as shown in (2.4), except that it is in partitioned form, and it reflects the specific assumptions made with respect to seafood vis a vis all other commodities.

In (2.36) F is an (nxn) submatrix, involving the seafood sector, in which the off diagonal elements may take on values of $\gtrless 0$, and G is a (k-1 x k-1) submatrix containing the partial derivatives of marginal utilities of all other commodities. Φ is the null matrix of order (nxk-1) and both Φ and Φ' reflect the assumption of independence between any species of fish and any of the other k-1 commodities. Finally, the price vectors $-P_F$ and $-P_G$ are respectively of order (nxl) and (k-lxl) and 0 is a scalar. In the process of finding the inverse of (2.36), we may make the following transformation:

$$(2.37) \quad (-P_F'F^{-1}P_F - P_GG^{-1}P_G)=1$$

Since the left hand side of (2.37) is a scalar under any circumstances, constraining (2.37) to one is equivalent to making a positive monotonic transformation of the original expression.[19] As a result of the transformation, the inverse of (2.36) becomes:

(2.38)

$$\begin{pmatrix} F^{-1}+F^{-1}p_F{}'p_F{}'F^{-1} & F^{-1}p_F p_G{}'G^{-1} & F^{-1}p_F \\ G^{-1}p_G p_F{}'F^{-1} & G^{-1}+G^{-1}p_G p_G{}'G^{-1} & G^{-1}p_G \\ p_F{}'F^{-1} & p_G{}'G^{-1} & 1 \end{pmatrix}$$

The matrix $(F^{-1} + F^{-1}p_F p_F{}'F^{-1})$ is of order nxn and, when multiplied by (the marginal utility of income), gives a matrix of substitution effects for all own and cross price partial derivatives among all species of fish. Thus, the typical price partial could be specified as,

$$(2.39) \qquad \frac{\partial x_i}{\partial p_j} = \lambda f_{ij} - x_j \frac{\partial x_i}{\partial y} ,$$

where f_{ij} is the ij^{th} element in (2.38). The vector $F^{-1}p_F$ represents the set of species income coefficients except that each element has the opposite sign of the true income derivative. The other elements refer to cross partials either between a given species of fish and commodities in the non-fish category or price partials between the other commodities (excluding fish), and also to the income

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[19] This assumes that the original expression is a positive scalar. This would be consistent with a value of $\frac{\partial \lambda}{\partial y} < 0$, i.e., diminishing marginal utility of income.

coefficients of the other k-1 commodities. Consequently, these elements are outside the scope of our analysis.

Two results directly follow from the transformation made in (2.37). First, it is possible to specify the income derivatives in the form $-F^{-1}p_F$. Secondly, since the $\frac{\partial \lambda^{\cdot}}{\partial y}$ is equal to the inverse of (2.37) multiplied by -1, we have, in effect, set $\frac{\partial \lambda}{\partial y} = -1$. Thus, the time series estimate, $\hat{\gamma}$ $(= {}^{-\lambda}/\frac{\partial \lambda}{\partial y})$ is identical to an estimate of the marginal utility of income, $\hat{\lambda}$. If we have all of the income derivatives, and n(n-1)/2 estimates for $\frac{\partial x_i}{\partial p_j}$, we can easily isolate income effects (at mean quantity levels). Then, given that the substitution effects have income effects embedded in them, we may isolate the latter and solve for n(n-1)/2 elements of the matrix F^{-1}. Let us denote an element of F^{-1} as F^{*}_{ij}, while F_{ij} refers to the 'total' substitution effect divided by $\hat{\lambda}$, i.e., that which includes the second order income effect. Because of the assumption of the existence of a continuously differentiable utility function, the matrix F^{-1} is symmetric. Therefore, we have only to find n more elements in F^{-1}.[20] However, we know that

$$(2.40) \qquad -F^{-1}p_F = h_i \ ,$$

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[20] This is true whether the n(n-1)/2 elements which comprise the initial set of independent estimates correspond exclusively to off-diagonal elements or to a combination of diagonal-off-diagonal elements.

where h_i is an nx1 vector of income coefficients. By rearranging (2.40) and using the symmetry characteristics, we can respecify so as to end up with a system of n equations and n unknowns. In other words, we can derive a vector Θ, such that,

$$(2.41) \quad \Theta = (h_i - \bar{F}^{-1}),$$

where $\bar{F}^{-1}$ is comprised of the known elements of F^{-1} multiplied by appropriate prices. It then follows that,

$$(2.42) \quad \Theta = PZ''$$

where p is an nxn matrix comprised of prices and zeroes, and Z" is an nx1 vector of the unknown elements of F^{-1}. Thus,

$$(2.43) \quad Z'' = P^{-1}\Theta ,$$

and we can find all of the components of F^{-1} and, as a consequence, all of the F_{ij}'s in $F^{-1} + F^{-1}p_F p_F' F^{-1}$. When all of the elements are multiplied by $\hat{\lambda}$, we will have a matrix of substitution effects.

On the basis of economic theory, it is required that the sign of $F_{ii} < 0$, and we would expect -- because of the close relationship among species -- that the F_{ij} $(i \neq j)$ are greater than zero.[21] In addition, we would expect that for

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[21]In Powell's study, where commodity classifications were fairly aggregative, the F_{ij} were all positive for $i \neq j$, although because of large income effects the uncompensated cross price derivatives were all negative, and thus every

the independent estimates, the uncompensated cross partial derivatives $\frac{\partial x_i}{\partial p_j}$ would be greater than zero, and of course, the uncompensated own partial to be less than zero. The parameters are -- given the reliability of the initial set of coefficients independently estimated -- unique up to a positive monotonic transformation.

3. Policy Implications

The estimation of all of the price derivatives would complete the empirical aspect -- in terms of parameter identification -- of this study, However, the policy implications have yet to be examined.

Not the least important aspect of this research is the application of a forecasting technique which is normally used in situations in which the individual commodities which comprise the analysis are all of an aggregated nature. The purpose of employing it in this context -- where seafood is obviously a much more disaggregated commodity -- is to place some realistic upper bounds upon the increase in projected consumption. That is, the constraint imposed by the expected budget and the consumption of other goods would tend, ceterus paribus, to reduce the rate at which expenditures on seafood can increase. Some obvious comparisons may be drawn between the forecasts derived here and those obtained using a tech-

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pair of commodities were gross complements. However, that the F_{ij} were greater than zero in this instance would, a fortiori, mean a positive sign for more disaggregated, more closely related and substitutable goods.

nique which does not take into account the type of restrictions imposed by the more aggregative approach.[22] This is particularly important for a resource related commodity. The lower the increase in rate of projected consumption, the less pronounced is the need for governmental intervention.

The second significant subtopic concerns the price changes caused by the supply restrictions. Let us make the assumption, as we did before, that of the n species, i belong to the constrained set. For the moment, let us ignore the impact of international ramifications and assume that we have a closed economy in which a replenishible fishery resource is harvested. Let us denote x_i^* as the vector of projected consumption for the i constrained species, x_i^c as maximum sustainable yield for these species, and Δx_i, as the ixl vector, in which

$$(2.44) \quad \Delta x_i = x_i^c - x_i^*$$

Since all of the projections will be made at least far enough into the future so that forecasted consumption is at least greater than maximum sustainable yield, it follows that all of the elements of Δx_i are negative. Given that all of

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[22] Just such a comparison will be discussed in more detail in chapter six.

the constrained markets clear at MSY,[23] we may estimate changes in the prices among the i constrained species on the assumption that the other species are in perfectly elastic supply. Defining F_i^* as the ixi submatrix containing all of the price partials between the constrained species, we can find i price changes as follows:

$$(2.45) \qquad F_i^* \Delta p_i = \Delta x_i ,$$

$$(2.46) \qquad \Delta p_i = (F_i^*)^{-1} \Delta x_i$$

The price changes in (2.46) reflect all of the interaction between own <u>and</u> cross partial derivatives. In similar fashion to the forecast, we would expect that the introduction of the general equilibrium framework on the demand side would dampen the rate of increase in prices relative to a set of changes obtained from a partial equilibrium framework, i.e., when quantity consumed is a function of own price only.[24] Thus, the need for government policy programs could very well, as before, be considerably reduced.

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[23] This assumption is vital so that we may solve for the i price changes. Otherwise, we would have a hopelessly underidentified system. Given enough time, however, it may not be an unrealistic assumption.

[24] Comparative price changes will be discussed in chapter six.

Finally, the allocative implications may be set forth as follows. Denoting F_{n-i}^{*} as the (n-i) x i submatrix of cross partials between the constrained and the unconstrained species, i.e., only those which refer to the change in the quantity of the unconstrained with respect to a change in the price of the constrained species, we have,

$$(2.47) \quad F_{n-i}^{*} \Delta p_i = \Delta x_{n-i}$$

where Δx_{n-i} refers to the (n-i)x1 vector of quantity adjustments of the unconstrained species made in the market. We may refer to the vectors Δx_{n-i} and Δp_i as the market price and quantity solutions respectively. On the other hand, let F_i^{**} represent the ixi submatrix of substitution effects between the constrained species. Then, a set of modified price changes $\Delta p_i'$, can be shown as,

$$(2.48) \quad F_i^{**} \Delta p_i' = \Delta x_i \,,$$

$$(2.49) \quad \Delta p_i' = (F_i^{**})^{-1} \Delta x_i$$

where Δx_i is as defined above, and $\Delta p_i'$ is a vector of ix1 price changes generated by a matrix of substitution effects. Letting F_{n-i}^{**} stand for the (n-i) submatrix similar to F_{n-i}^{*}, except that it contains only substitution effects, we may solve for the set of quantity adjustments which leaves society as well off as at the originally projected bundle:

$$(2.50) \quad F^{**}_{n-i} \, \Delta p_i' = \Delta x'_{n-i}$$

where $\Delta x_{n-i}'$ is of order (n-i)x1. Let $\{ x^*_{n-i} \}$ represent the originally forecast set of unconstrained species. The difference between the set generated by the market $\{x^*_{n-i}+\Delta x_{n-i}\}$ and the constant utility set $\{x^*_{n-i}+\Delta x^*_{n-i}\}$ measured in terms of the original set of prices -- is the general equilibrium measure of the loss to society imposed by the resource constraint coupled by the free-access market mechanism.[25]

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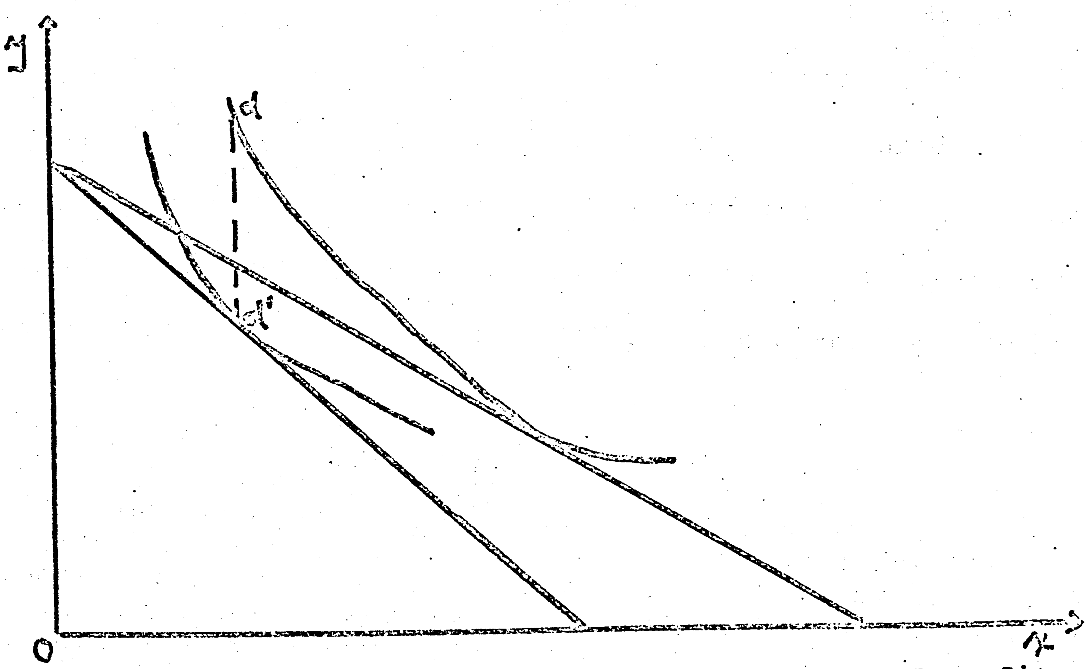
[25] In other words, this is the n-dimensional analogue of what is referred to as the quantity-equivalent variation. Diagrammatically, the quantity-equivalent measure is given by "(dd')" in the figure below.



Within the context of a closed economy, the benefits of a program to redistribute effort so as to arrive at a combination denoted by "d" would be measured by a new set of prices; namely, that set of prices at which the bundle "d" would clear the market.

If that difference is relatively large, then a policy aimed at a redistribution of effort should be directed toward the attainment of certain output levels as minimum goals, given by x_i^{**},

$$(2.51) \qquad x_i^{**} = \begin{pmatrix} x_i^c \\ x_{n-i}^{*} + \Delta x'_{n-i} \end{pmatrix}$$

where both x_i^c and $(x_{n-i}^{*} + \Delta x'_{n-i})$ have already been defined. In that case, the level of capital and labor to be reallocated can be determined by simply multiplying the increased level of output by the respective capital-output and labor-output ratios of the constrained species.[26]

On the other hand, if the difference between the market solution and the solution generated by the constant utility locus is of the second order of smalls, then that too is significant since it implies that the market (with some possible slight adjustments imposed via a quota) makes rather 'optimal' adjustments under suboptimal conditions.

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[26] We have, of course, assumed a closed economy. Empirically, however, the United States is a net importer of seafood, and those species which are primarily affected fall almost entirely into the constrained set category. Nonetheless, we may abstract from international considerations by assuming that the United States consumes some long-run share of maximum sustainable yield for the constrained species and that the incremental output of the unconstrained species implicit in (2.51) can be produced domestically. For further explanation, see chapters five and six.

Whichever outcome is derived, the framework of a more general equilibrium analysis will help focus attention to resource problems traditionally handled in a partial frame of reference.

CHAPTER III

TIME SERIES ANALYSIS

1. Introduction

While previous chapters have highlighted the earlier literature and outlined the basic demand model, this chapter will concentrate upon all factors related to the time series aspect of this study. Chapter four goes into a detailed discussion of the cross-sectional component, reconciles the results of the latter with the "control totals" established by the time series estimates, and derives all of the price partials. Chapter five will then derive a series of forecasts of seafood consumption expenditures for a series of years into the future and will make explicit the assumptions needed to relate the predicted level of consumer expenditures to the resource constraint in the relevant subsectors of the fishing industry. Finally, chapter six consists primarily of a discussion of policy implications.

The structure of this chapter may be subdivided into three parts. The first section includes a discussion of the specific computational methods used in the implementation of the model described in the previous chapter. The second section describes the basic data used in the time series analysis and explains the commodity classifications employed. The last part summarizes the basic findings and presents some conclusions.

2. Computational Model

The estimation procedure described in chapter two may be computationally broken down into a two stage process. First, γ is computed using the formula,

$$(3.1)\quad \hat{\gamma} = \frac{|R|}{|Z|}$$

where Z is as defined before, and R is equal to:

$$(3.2)\quad R = \left(\begin{array}{c|ccccc} & & & H' & & \\ \hline & \Omega & 0 & \cdots & \cdots & 0 \\ & 0 & \Omega & & & \vdots \\ \phi & & & \Omega & & \vdots \\ & & & & \Omega \cdots & \vdots \\ & 0 & \cdots & \cdots & \cdots & \Omega \end{array}\right)$$

All of the components of R have already been defined in the previous chapter, and the dimension of R, like Z, is (2k+1) x (2k+1). An easy way to compute (3.1) is given by the following,

$$(3.3)\quad \hat{\gamma} = \frac{\sum_{i=1}^{K} |T_i|}{\sum_{i=1}^{K} |L_i|},$$

in which,

$$(3.4)\quad T_i = \begin{pmatrix} \sum_t Z_{it} q_{it} & \sum_t u_t Z_{it} & \sum_t t Z_{it} \\ \sum_t u_t q_{it} & \sum_t u_t^2 & \sum_t t u_t \\ \sum_t t q_{it} & \sum_t t u_t & \sum_t t^2 \end{pmatrix}$$

and,

$$(3.5)\quad L_i = \begin{pmatrix} \sum_t Z_{it}^2 & \sum_t u_t Z_{it} & \sum_t tZ_{it} \\ \sum_t u_t Z_{it} & \sum_t u_t^2 & \sum_t tu_t \\ \sum_t tZ_{it} & \sum_t tu_t & \sum_t t^2 \end{pmatrix}$$

Given an initial set of expenditure coefficients, the first row and column of the T_i and L_i matrices can be obtained and (3.3) may then be derived. The second stage of the estimation procedure involves the computation of the observation vector y_{it} on the variables u_t and t. However, due to the transformation made in the system, running OLS regressions for each equation in the system ensures that the identities that have been superimposed on these equations are maintained -- namely, that $\sum_{i=1}^{k} b_i \equiv 1$ and $\sum_{i=1}^{k} c_i \equiv 0$.[1]

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[1] This may be easily demonstrated as follows. For any given equation, we have

$$(1.1)'\quad \text{Min} \sum_t (y_{it}-b_iu_t-c_it)^2$$

Differentiating (1.1) with respect to b_i and c_i and setting equal to zero, we find that,

$$(1.2)'\quad \sum_t y_{it}u_t = b_i \sum_t tu_t + c_i \sum_t t^2$$

Solving for c_i in (1.3)', and substituting back into (1.2)', we obtain an expression for b_i, namely,

$$(1.4)'\quad b_i = \frac{\sum_t u_{it}u_t \sum_t t^2 - \sum_t y_{it}t \sum_t tu_t}{\sum_t u_t^2 \sum_t t^2 - \sum_t tu_t^2}$$

A new set of b_i are then generated and the process described above repeated. Convergence is defined as the condition that $\hat{\gamma}$ in iteration m is equal to $\hat{\gamma}_{m+1}$, $\hat{\gamma}_{m+2}$, and so on. The computational method utilized for each iteration gives all of the elements of $\hat{\Psi}$ (the vector of parameters), and is identical to the coefficients estimated by the RHS of (2.22). In addition, the condition for convergence described here gives the same results in terms of the final parameters as does the theoretical criterion for convergence described in

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Given that the demoninator in (1.4)' remains constant and does not depend upon "i", and given that $\sum_i y_{it} \equiv u_t$, it follows that,

$$(1.5)' \quad \sum_{i=1}^{k} b_i = \frac{\sum_t t^2 \sum_t u_t^2 - \sum_t tu_t^2}{\sum_t t^2 \sum_t u_t^2 - \sum_t tu_t^2} \equiv 1$$

The solution for c_i in (1.3)' is given by

$$(1.6)' \quad c_i = \frac{\sum_t y_{it} t - b_i \sum_t tu_t}{\sum_t t^2}$$

Summing (1.6)' over i, we have,

$$(1.7)' \quad \sum_{i=1}^{k} c_i = \frac{1}{\sum_t t^2} [\sum_i (\sum_t y_{it} t - b_i \sum_t tu_t)]$$

$$= \frac{1}{\sum_t t^2} [\sum_i \sum_t y_{it} t - \sum_i (b_i \sum_t tu_t)]$$

$$= \frac{1}{\sum_t t^2} [\sum_t (t \sum_i y_{it}) - \sum_t tu_t]$$

$$= \frac{1}{\sum_t t^2} [\sum_t tu_t - \sum_t tu_t] \equiv 0$$

chapter two.[2] Thus, the only essential difference between the system outlined in the last chapter and the technique adopted here to estimate the parameters of that system lies in the ease of computation of the latter.

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[2] This iterative procedure is very similar to a generalized least squares routine used by Powell, Van Hoa, and Wilson, "A Multi-Sectoral Analysis of Consumer Demand in the Post-War Period, in <u>The Southern Economic Journal</u>, Vol XXXV, No. 2, pp. 109-120. Ignoring differences in specification, the vector $\hat{\psi}$ is estimated by,

(2.1)' $\hat{\psi} = (W^T D^{-1} W)^{-1} W^T D^{-1} q$

In (2.1)', W is an independent variable observation matrix made up of a diagonal matrix --- comprised of all of the exogenous variables that appear in every equation --- and a column vector of elements (y_{it}) that are different in each equation. q is the vector of dependent-variable observations. D is a knxkn diagonal matrix -- k equal to the number of equations, n the number of observations -- whose elements are $\sigma_1^2 \ldots\ldots \sigma_1^2$, $\sigma_2^2 \ldots\ldots \sigma_2^2 \ldots\ldots \sigma_k^2 \ldots\ldots \sigma_k^2$
The assumptions underlying D follow classical precepts: homoscedasticity and zero serial correlations within equations, and zero contemporaneous and serial inter-equation error covariances.

There are principally two differences between the method used here and the procedure followed in (2.1)'. First, in (2.1)', an initial set of expenditure parameters is used to derive the Z_{it}'s and - in effect - the procedure parallels the first iteration followed here -- so that the elements of D are then found by computing σ_i^2 from the several equations. The new set $[b_i]$ is then used to construct the Z_{it}'s and (2.1)' is computed. However, D is not changed from iteration to iteration. The technique used here -- adopted by Powell in his article on the Australian economy -- would be equivalent to using (2.1)' - except that D would be changed at each iteration. The second important difference relates to the fact that D is not known ex ante; i.e., even if D were to be changed at each iteration, the D employed in iteration m is derived from parameters obtained in iteration m-1. The method employed here would be equivalent to using a D_m consistent with parameters in iteration m.

3. Data

The commodity classifications outside of the fish consumption category were chosen so as to be fairly aggregative in nature in order to preserve the plausibility of the additivity assumption with respect to the utility function. Altogether, consumer expenditures in the United States were subdivided between the following five categories: (1) fish, (2) all other food, (3) all non-durable commodities (excluding food), (4) consumer durables, and (5) services. The definitions outside of the food classifications generally follow categorizations developed in the Survey of Current Business.[3] Table 3.1 presents the breakdown between commodity groupings. Table 3.2 and 3.3 present per capita expenditures and price indices respectively for these five commodity groups for the years 1952-1967. Thus, a price index is used for the price variable, and expenditures deflated by the relevant price index is used as an indicator of real quantities. The values of time ("t") for the period 1952-1967 run from "-7" to "+8".[4] Finally, initial estimates

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[3] Survey of Current Business, July, 1970, [p.29] has the breakdown categorized. Except for the "Food and Beverage" group, all others follow that listing.

[4] This, of course was arbitrary. For most of the studies of this nature, the number of years selected is odd, so that $\Sigma_t t \equiv 0$.

Table 3.1

Commodity Groupings*

1. All Seafood

2. All Other Food

   All Food Purchases Minus Seafood, Minus Alcoholic Beverages and Tobacco Products

3. All Other Non-Durable Commodities

   a. Alcoholic Beverages

   b. Tobacco products

   c. Clothing and shoes

   d. Gasoline and oil

   e. Other nondurable goods (excluding tobacco products)

4. Durable goods

   a. Autos and parts

   b. Furniture and household equipment

   c. Other durable goods

5. Services

   a. Housing

   b. Household operation services

   c. Transportation services

   d. Other services

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* Source for categories 3-5: Survey of Current Business, National Income Issue, July, 1969, p. 49. Seafood expenditures estimates were obtained from the Bureau of Commercial Fisheries; category 2 was calculated by differencing the seafood from the food group. The latter is also published in the Survey of Current Business.

Table 3.2

Per Capita Expenditures by Commodity*

	t	Seafood	All Other Food	All Other Non-durable Commodities	Durable Commodities	Services	Per capita expenditures Total
1952	-7	12.2816	337.491	378.84	187.566	469.298	1385.48
1953	-6	11.61895	337.251	385.874	209.156	502.837	1446.75
1954	-5	11.55276	337.661	381.421	202.837	527.415	1460.89
1955	-4	10.79887	341.012	395.204	240.136	553.908	1541.06
1956	-3	11.18584	348.369	409.458	231.545	585.961	1586.52
1957	-2	12.2282	360.99	418.834	238.307	613.645	1644.
1958	-1	12.5854	370.024	422.173	217.521	643.334	1665.64
1959	0	12.3955	373.96	441.392	250.126	679.019	1756.89
1960	1	12.1173	377.416	451.031	251.644	714.765	1806.97
1961	2	12.5245	381.194	457.945	241.346	737.852	1830.86
1962	3	12.9021	387.232	474.345	266.502	769.057	1910.04
1963	4	12.713	392.846	488.291	285.851	807.928	1987.63
1964	5	12.6887	409.986	512.901	309.538	853.317	2098.43
1965	6	13.3056	429.529	542.946	342.12	905.358	2233.26
1966	7	14.28	455.318	586.613	361.121	962.858	2380.19
1967	8	14.6587	458.254	614.018	368.99	1032.04	2487.96

Source: Survey of Current Business, and Bureau of Commercial Fisheries.

Table 3.3

Price Indices For Five Commodity Groups*

Year	Seafood	All Other Food	All Other Non-durable Commodities	Durable Commodities	Services
1952	.974	.953	.929	.954	.836
1953	.938	.938	.938	.943	.877
1954	.943	.936	.945	.929	.900
1955	.924	.922	.948	.919	.920
1956	.923	.929	.967	.949	.946
1957	.935	.96	.993	.984	.973
1958	1.000	1.000	1.000	1.000	1.000
1959	1.018	.984	1.012	1.014	1.030
1950	1.02	.995	1.025	1.009	1.058
1961	1.042	1.007	1.031	1.006	1.076
1962	1.085	1.017	1.038	1.008	1.090
1963	1.083	1.031	1.048	1.004	1.109
1964	1.058	1.044	1.053	1.004	1.131
1965	1.089	1.068	1.068	.996	1.151
1966	1.16	1.121	1.09	.987	1.183
1967	1.194	1.13	1.124	1.003	1.221

*Source: For all categories except "Seafood", OBE Implicit Price Deflators were used for the relevant price indicators. That is, for "Durable Commodities", "Services", and "All Other Food", the deflators were taken directly from the Survey of Current Business (July 1969 and 1970 issues, and National Income Account Supplement). For the classification, "All Other Non-Durable Commodities", a weighted average of the indicators of components listed in Table 3.1 (with weights based upon expenditures in the base year, 1958) was used. Finally, the "Seafood" price indicator is the BLS estimate of the CPI for seafood purchases. Although not all seafood commodities are included in deriving this index, in terms of value it is a fairly good indicator of the direction of change of total seafood cost. In other words, the seafood commodities that are included in the index comprise a fairly large proportion of the total value of seafood purchases, and thus, over a long period of time the BLS index would represent a fairly accurate price index.

of the expenditure coefficients for these product delineations were taken from a study undertaken by Powell and modified so as to be consistent with the present research.[5]

4. Results

The actual regression that was fitted was of the form,

$$(3.6)\quad Y_{it} = b_i u_t + c_i t + e_{it},$$

where all variables have been previously defined. The results in terms of the final regression coefficients, t values, and R^2 for each equation, are given in Table 3.4. Our computational resources precluded absolute convergence: convergence to 4 places was achieved in three iterations (see

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[5]The following estimates were used: Clothing .070; Housing .022; Household Operation .062; Furniture and Durables .130; Private Transportation.340; Public Transportation .018; Miscellaneous Non-Durables .065; Services .204; Food .089. Services, Private Transportation, Public Transportation, Housing and Household Operation were put under the "Service" category; Furniture and Durables were put under the "Durables" category; Miscellaneous Non-Durables and Clothing were placed under "non-Durable Commodities;" Seafood was put under that listing; and finally, the difference between the coefficient for Seafood and that for Food was put in the Food grouping. Accordingly, the initial estimates were: Services, .646; Durables, .130; Non-Durables, .135; Food (excepting Seafood) .08869; Seafood .00031. The latter estimate was obtained from Rauniker and Purcell (28), and the difference between Rauniker and Purcell's estimate and Powell's figure for food was used as the initial expenditure coefficient for food. There naturally were some commodities which were not exactly matched, e.g. alcohol was estimated in the food category but included here in the non-durable commodity classification. Problems also arise because of the obvious overlap between the "service" and "non-durable" groups. Nonetheless, because the converged value of all of the parameters was "unique" an exact correspondence of initial expenditure coefficients between commodities does not constitute a major problem.

Table 3.4

Major Results Of Time Series Analysis

Commodity	b value	c value	t ratio for b	t ratio for c	R^2y^1	R^2v^1	Durbin-Watson Statistic *
1. Seafood	.002032	-.067010	1.5933	-1.2242	.192	.889	1.402 *
2. All Other Food	.082021	-.287165	7.6307	- .6224	.968	.995	1.118 **
3. All Other Non-durable Commodities	.288561	-3.17945	17.2800	-4.4360	.991	.996	1.666 *
4. Durable Commodities	.275104	-4.04716	8.7782	-3.0088	.957	.978	1.791 *
5. Services	.352282	7.58079	13.5777	6.8074	.996	.998	1.358 *

Total 1 Total 0

Following Powell, we define R^2y and R^2v respectively as:

$$(1.1)' \quad R^2y = 1 - \sum_t e_{it}^2 \Big/ \sum_t (y_{it})^2$$

$$(1.2)' \quad R^2v = 1 - \sum_t e_{it}^2 \Big/ \sum_t (V_{it} - \bar{V})^2$$

*Insignificant at the .05 level, i.e. accept null hypothesis of no autocorrelation.

**Significant at the .05 level, i.e. reject null hypothesis of no positive autocorrelation.

Appendix B). However, once reached a value of 1,030.0, it fluctuated between 1,030.0 and 1,031.0. Since the set of regression coefficients (b_i) and (c_i) were not sensitive to the fluctuations between these two values, one of the more frequently occurring values, 1,030.3 was selected as the "converged" value of $\hat{\gamma}$. Another important characteristic of the computational process was the apparent insensitivity of the final parameters to the initial set of expenditure coefficients utilized. In other words, the final value of $\hat{\gamma}$ always converged to the range of 1,030.0 to 1,031.0 even after some of the original estimates were drastically changed. A number of experiments were performed in which the expenditure coefficients with which the iterative procedure was initiated were rearranged in value, so that those commodities which at first had the highest value were given relatively low estimates, and those commodities which at the outset were very small were given large values.[6] However, in all cases the range of convergence was not affected.

The final estimates did not differ too much from our <u>a priori</u> expectations. The expenditure coefficient for all seafood showed that out of an additional $1,000 of total spending $2 would be spent for seafood consumption. This is fairly reasonable, especially in comparison to the expend-

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[6] In running these experiments, the constraint that $\sum_{i=1}^{k} b_i = 1$, was, of course, maintained.

ture coefficient for all other food (.082). However, the seafood expenditure parameter was insignificantly different from zero at the .05 level of significance. In addition, the explanatory power of the independent variables was very low -- R^2_y was only 0.19. Nonetheless, while these estimates were reasonable in the sense that income is not an important factor relative to other commodities in the explanation of aggregate fish consumption, the results are meaningful for a number of reasons. First, the implied income elasticity, evaluated at mean expenditures, is given by

$$(3.7) \quad E_i = b_i \frac{\bar{m}}{\bar{v}}$$

where E_i is the income elasticity. For seafood, this estimate is equal to .29, which is comparable to estimates used by others.[7] Second, the t value for the expenditure parameter was significant at the .10 level and the computed value of t was fairly close to the critical t ratio for the .05 level.[8]

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[7] See FAO World Indicative Plan for Agricultural Development, chapter 1, p. 10. The estimate for the income elasticity for North America used there is equal to .20.

[8] There was not a high degree of autocorrelation, so that the t ratio was not overestimated for that reason. The Durbin-Watson statistic was approximately equal to 1.41 which for 16 observations falls into the rejection region. On the other hand, multicollinearity -- which is clearly high in this instance -- can cause t ratios to be underestimated. However, while the simple correlation coefficient between u_t and t was equal to .95, the important question

In addition, it is possible that while aggregate fish expenditures are not sensitive to income certain individual components are. This will be more closely examined in the next chapter. Third, a low R^2y in this context is not at all devoid of significance; that is, given the high R^2y for all of the other equations in the system, and because of the adding-up constraints, a high degree of explanation for n-1 equations ensures a high degree of explanation for n equations. It follows, then, that the use of a single equation within the framework of a system of equations for forecasting purposes is, in this particular instance, quite reasonable. Thus, given a reliable forecast for u_t -- which, in effect, requires a reliable estimate of m_t -- a fairly good estimate of y_i for a given year t can be obtained. Fourth, the explanatory power of all of the equations in-

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really is, "What is the net impact of multicollinearity in in the n-1 equations?" In other words, if the introduction of time into the equations has not affected the sum of the expenditure parameters from the four other equations, then the net effect upon the seafood function would be negligible. Since seafood is such a small proportion of total expenditures, it appears rather plausible that -- if anything -- the relation between the four other expenditure coefficients was upset, but not their total. Furthermore, for all of the other equations, the t ratio for the b_i is significant even after time is introduced. Thus, multicollinearity is not a factor for n-1 equations, and therefore is not of further import for the seafood equation. Even if it were, the net effect would be an increase in the t ratio of b_F. Thus, from the point of view of either significance or absolute magnitude, the effect of multicollinearity may be inconsequential.

increases when the goodness of fit is measured by R_v^2. This is most pronounced for the aggregate fish commodity grouping; whereas R^2y was only 0.19, R_v^2 was 0.89. In other words, the goodness of fit is approximately three and one-half times better with respect to expenditures than in relation to the variable y_i -- and it is the former which is of primary concern within a forecasting context.

In summary, then, it is clear that while most of the time series results were not surprising, they were in many respects meaningful, especially in a forecasting framework.

CHAPTER IV

THE CROSS-SECTIONAL STUDY AND THE FORMULATION OF THE PRICE DERIVATIVES

1. Introduction

The next stage of the estimation process involves the use of cross-sectional results which, when combined with the major parameters derived in chapter three, will enable us to identify all of the own and cross price partial derivatives with respect to n species of marine resources. More specifically, when we combine a given set of reliable 'independent' information taken from the cross-sectional study with the time series estimated parameters, $\hat{\lambda}$ -- the marginal untility of income,[1] $\hat{b}_F$ -- the control total of the expenditure coefficient for all seafood, and $\bar{p}f$, the mean price index for seafood for the 1952-67 period, we will have a basis upon which to obtain all of the price derivatives. Section two describes the method employed to derive the independent information, i.e., general specification of the equations that were run using the cross-sectional data, which variables were included, etc.; section three discusses the sample data; part four presents the general results; section five goes into a

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[1] It is important to note that the parameter actually estimated in the time series analysis was $-(\lambda/\frac{\partial\lambda}{\partial y})$. However, when $\frac{\partial\lambda}{\partial y}$ is set equal to -1, the estimate becomes equal to $\hat{\lambda}$, the marginal utility of income. The importance of this assumption is fully explained in Appendix D.

detailed formulation of the price derivatives consistent within a general equilibrium framework; and, finally, part six discusses some of the basic conclusions of this chapter.

2. Methodology

The methodology for the cross-sectional study parallels the form of the time series analysis in the sense that a series of linear expenditure equations were run, by species, across households (groups of households) across regions. The general form of the equations was,

$$(4.1) \quad v_{il} = \sum_{j=1}^{n} a_{ij} p_{jl} + \sum_{j=1}^{m} c_j x_{jl} + b_i y_l ,$$

where,

$$(4.2) \quad a_{ij} = p_i \frac{\partial x_i}{\partial p_j} + \delta_{ij} x_i , \quad \delta_{ij} \begin{array}{l} = 0 , \quad i \neq j \\ = 1, \quad i = j \end{array}$$

V_{il} is equal to per capita expenditure for the i^{th} species by the l^{th} household (or group), x_{jl} relates to family size or socio-economic variables such as race, religion, etc., or to regional variables, and b_i is the income coefficient.

The price variable needs some clarification. Because the price variable for the time series study was a price index, the price specification for the cross-sectional study will be in the form of a relative price. That is, the relevant species price variable will appear in index form as the price paid by household l relative to the national average price for the particular species computed from the sample data.[2] In addition, certain adjustments have been made in order to account for household consumption away from home.[3]

Several types of equations using the specification given in (4.1) were fitted and the 'best' were selected. Several criteria for selection had to be used. For example, equations on a micro-household level were run for each species as well as on a grouped data (aggregated by level of income) basis. A combination of factors in addition to goodness of fit were used as criteria for selection: statistical significance of individual parameters, relative consistency with other studies, etc. In general, the socio-economic variables included were (1) family size,[4] (2) two dummy variables for relition[5] (Jewish and Catholic), (3) one

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[2]Another added benefit -- although of minor importance -- of using prices in ratio form is that the effects of heteroscedasticity are minimized. This is usually a problem in cross-sectional work.

[3]The only observation that we had with respect to consumption of seafood away from home was number of meals away from home. In order to account for this factor, we made two basic adjustments. First, we used conversion factors to convert from number of meals to product weight (conversion factors were taken from Agriculture Handbook No. 284). Secondly, on the assumption that relative prices for seafood consumed at home were a good proxy for relative prices of seafood consumed away from home, we used those prices and derived an expenditure estimate for seafood consumed in restaurants, etc. While this perhaps gave an underestimate of actual expenditures away from home for seafood, it provided one way of abstracting from this factor in a way that would not bias the income parameter.

[4]For grouped data, this variable was defined as "group size."

[5]For grouped data, a continuous variable defined as number of Jewish, number of Catholic, in a given group was used.

dummy variable for race.[6] These, along with income and price variables for all species were prespecified for all equations. Regional dummy variables were added in some cases in order to capture the impact of differences in taste among regions. We would expect that for those species which are not marketed nationally regional variables would be significant. The latter, therefore, would not only measure differences in taste, but, in addition, would measure the impact of the lack of low cost channels of distribution. We are not interested in this factor *per se*, but only in the context of obtaining more significant estimates of the economic variables, especially with respect to the prices of other species and income.

The species that were statistically fitted are not exhaustive, in the sense that they do not comprise 100% of seafood expenditures. However, since only some minor categories were omitted, this does not constitute a major shortcoming. There are eight major species in this study: (1) Shrimp, (2) Crabs, (3) Lobsters, (4) Tuna, (5) Salmon, (6) Groundfish, (7) Scallops, (8) Oysters-Clams.[7] This means that there will be a total of 8x8=64 price derivatives. In the cross-sectional study, we will select all of the implied own price

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[6]For grouped data, a continuous variable defined as number of Negroes in a given group was used.

[7]Which of these species falls into the constrained category and which into the unconstrained category will be discussed in chapter five.

derivatives, and ((nxn-n)/2)-n) or 20 of the most significant (according to t values) cross partials. We will conclude with a simplified test of the price derivatives to see if they can explain some of the quantity movements in the past, given the past behavior of price changes.

3. Data

The cross-sectional survey was conducted in 1969 by the National Marine Fisheries Service across 1,500 households. The sample households were regionally, ethnically and racially distributed so that they were fairly representative of the characteristics of the population of the United States in 1969. Questions with respect to quantity purchased and prices were answered every two weeks and then tabulated to derive an annual per capita expenditure, product weight, and price.

An important feature of this survey is the fact that the sample of households observed ranged over the entire country, so that large and permanent differences in price for a given species and between species could be obtained. Thus, the measurement of long-run income parameters and price parameters is a possible outcome in the regression equations. Additionally, this survey does not suffer from the shortcomings found in other cross-sectional studies in which households are interviewed in one area only.[8]

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[8]An example of this may be found in the work of Rauniker and Purcell, in which time series and cross-sectional data

4. Results

The results of the equations that were run are summarized in Tables 4.1 to 4.8. For the most part, household level regressions were used. The grouped data -- comprised of nine different income classes for each of the nine regions -- gave higher R^2 (as would be expected), but did not contain as many significant parameters. Only for scallops and oysters/clams were the aggregated results used.

In some instances, regional variables were included, but the main criterion as to whether any regional variable was included for a given species was based upon an increase in R^2 adjusted for degrees of freedom, without a concomitant decline in the significance of the economic variables.[9]

Our discussion of the regression results will be subdivided into two parts. First, we will include a brief summary of the impact of the non-economic variables: the major socio-economic parameters, in particular, the results concerning family size (group size where appropriate), race and religion; and a brief presentation of the importance

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are pooled. See, Analysis of Demand for Fish and Shellfish, J.C. Purcell and Robert Rauniker, Research Bulletin 51, University of Georgia, College of Agriculture Experiment Station.

[9]This procedure was used for the following reason. Since the purpose of the cross-sectional estimates was to derive long-run structural parameters rather than good predicting equations *per se*, an increase in R^2 alone would not have been adequate. On the other hand, regional variables, in many instances, are really a proxy for specific price conditions in a particular area, and not an indicator of different tastes.

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.1 Shrimp*

Variables	Regression	T Ratio
1. Constant	- .15422808	
2. Family Size	- .38971170	- 1.996
3. Jewish	.39735955	.2346
4. Catholic	.20096034	.3430
5. Negro	.94626299	.8803
6. Income	$.57201015 \times 10^{-3}$	5.337
7. Price of Shrimp	.36276636	.7522
8. Price of Oysters/Clams	.43292527	.6944
9. Price of Tuna	1.2927260	1.133
10. Price of Lobsters	.49173035	.9758
11. Price of Crabs	- .30729344	- .5468
12. Price of Groundfish	- .34823279	- .7025
13. Price of Scallops	1.8690439	1.612
14. Price of Salmon	- 1.9728542	- 2.047

R^2=.2105
F(13,131)=
5.229
269 observations
*Household Level

Table 4.2 Crabs*

Variables	Regression	T Ratio
1. Constant	- 2.5973228	
2. Family Size	- .51076755	- 2.095
3. Jewish	- .29550586	- .1700
4. Catholic	.16485509	.2125
5. Negro	1.0459726	.7980
6. Income	$.15292862 \times 10^{-3}$	1.453
7. Price of Shrimp	- 1.3957403	- 1.196
8. Price of Oysters/Clams	2.4533307	4.561
9. Price of Tuna	.2333424	.1770
10. Price of Lobsters	- .79732715	- 1.271
11. Price of Crabs	.37532200	.9727
12. Price of Groundfish	.90026434	1.349
13. Price of Scallops	1.4914521	1.880
14. Price of Salmon	1.8757360	1.273

R^2=.2896
F(13,131)=
4.108
145 observations
*Household Level

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.3 Lobsters*

Variables	Regression	T Ratio
1. Constant	1.0561374	
2. Family Size	- 2.3567350	- 1.730
3. Jewish	12.494558	1.588
4. Catholic	2.6911149	.7357
5. Negro	- 1.0744252	- .1751
6. Income	$.99434587 \times 10^{-3}$	1.732
7. Price of Shrimp	- 10.333537	- 1.470
8. Price of Oysters/Clams	3.5462620	1.246
9. Price of Tuna	8.4653988	1.456
10. Price of Lobsters	- 1.4358317	- .4544
11. Price of Crabs	- 4.0015255	- 1.639
12. Price of Groundfish	7.2728524	1.757
13. Price of Scallops	3.3904472	.4109
14. Price of Salmon	- 2.3470448	- .3951
15. Region 1 (New England)	11.783367	2.670

R^2 = .2655
F(14,88) = 2.272
103 observations
*Household Level

Table 4.4 Tuna*

Variables	Regression	T Ratio
1. Constant	2.1551427	
2. Family Size	- .53630125	- 2.181
3. Jewish	4.7877022	3.234
4. Catholic	1.2869883	1.563
5. Negro	1.3242350	.7351
6. Income	$.52064527 \times 10^{-3}$	4.087
7. Price of Shrimp	.29495419	.2454
8. Price of Oysters/Clams	- 1.3211467	- 1.932
9. Price of Tuna	1.4256136	1.134
10. Price of Lobsters	- 2.2623598	- 2.732
11. Price of Crabs	- 1.2179128	- 1.511
12. Price of Groundfish	- 0.65698295	- .2570
13. Price of Scallops	2.6118043	1.489
14. Price of Salmon	1.3856402	1.039
15. Region 3 (E. North Central)	- 2.7532983	- 1.258

R^2 = .1144
F(14,553) = 5.102
568 observations
*Household Level

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.5 Salmon*

Variables	Regression	T Ratio
1. Constant	3.5728217	
2. Family Size	- 1.3031244	- 7.116
3. Jewish	1.6826125	1.501
4. Catholic	.84853194	1.339
5. Negro	1.6436091	1.486
6. Income	- $.35369545 \times 10^{-3}$	- 3.760
7. Price of Shrimp	- .94772349	- .9974
8. Price of Oysters/Clams	1.4097796	2.443
9. Price of Tuna	3.5008448	3.118
10. Price of Lobsters	- 1.5162591	- 2.446
11. Price of Crabs	- 2.5926624	- 3.485
12. Price of Groundfish	.083418719	.4802
13. Price of Scallops	2.6179570	1.806
14. Price of Salmon	1.9080569	2.214
15. Region 6 (E. South Central)	4.3450070	3.681

$R^2 = .1648$
$F(14,649) = 9.147$
664 observations
*Household Level

Table 4.6 Groundfish*

Variables	Regression	T Ratio
1. Constant	3.5728217	
2. Family Size	- .87508520	- 6.109
3. Jewish	4.4276207	4.715
4. Catholic	.89307483	1.510
5. Negro	.85757961	.8395
6. Income	$.4822618 \times 10^{-4}$	.5901
7. Price of Shrimp	$.20798203 \times 10^{-2}$	$.2904 \times 10^{-2}$
8. Price of Oysters/Clams	1.1366709	2.799
9. Price of Tuna	.33975922	.3528
10. Price of Lobsters	- .91863856	- 1.939
11. Price of Crabs	- .62263491	- 1.227
12. Price of Groundfish	.28358664	1.985
13. Price of Scallops	.53539537	.5194
14. Price of Salmon	1.2849187	1.583

$R^2 = .1224$
$F(13,686) = 7.363$
700 observations
*Household Level

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.7 Scallops*

Variables	Regression	T Ratio
1. Constant	$.75990320 \times 10^{-2}$	
2. Family Size	$-.10408690 \times 10^{-2}$	- .3577
3. Jewish	$-.55673546 \times 10^{-2}$	- .2961
4. Catholic	$.24893807 \times 10^{-2}$	.4471
5. Negro	- .010530830	- .7003
6. Income	$.22100429 \times 10^{-4}$	.8305
7. Price of Shrimp	- .24718550	- .8012
8. Price of Oysters/Clams	.14102436	1.587
9. Price of Tuna	.90205951	1.244
10. Price of Lobsters	.064512793	.4244
11. Price of Crabs	- .31757226	- .9826
12. Price of Groundfish	- .25461606	- .8327
13. Price of Scallops	- .31067389	- 1.538
14. Price of Salmon	.23483592	.9983
15. Region 1 (New England)	.57676508	2.663
16. Region 3 (E. North Central)	- .092433424	- .4404
17. Region 4 (W. North Central)	- .35238189	- 1.697
18. Region 5 (South Atlantic)	.14491541	.6309
19. Region 6 (E. South Central)	- .33413667	- 1.378
20. Region 7 (W. South Central)	- .20323267	- .7543
21. Region 8 (Mountain)	.42891991	1.869

R^2=.5200
F(20,38)=
2.058
59 observations
*Group Data

Table 4.8 Oysters/Clams*

Variables	Regression	T Ratio
1. Constant	- .69186598	
2. Family Size	$.16764543 \times 10^{-2}$	.3778
3. Jewish	- .011206073	- .4221
4. Catholic	$-.62880804 \times 10^{-2}$	- .7496
5. Negro	.012111786	.5860
6. Income	$.19404949 \times 10^{-4}$	.4970
7. Price of Shrimp	.22734418	.5050
8. Price of Oysters/Clams	.082459048	.6658
9. Price of Tuna	1.9810963	2.124
10. Price of Lobsters	- .10145901	- .6436
11. Price of Crabs	- .22149882	- .8938
12. Price of Groundfish	- .22328715	- .4813
13. Price of Scallops	- .14894086	- .5037
14. Price of Salmon	- .30010058	- .8315
15. Region 3 (E. North Central)	- .52994178	-1.916
16. Region 4 (W. North Central)	- .40008992	-1.517
17. Region 6 (E. South Central)	1.1130824	3.852

R^2-.4436
F(16,54)=
2.690
*Group Data

of the regional variables. The second part will consist of a detailed discussion of the economic variables, i.e., the income coefficients and the own and cross price derivatives.

A. Socio-economic Variables

In practically all cases, the effect of family size upon per capita expenditures of individual species was negative and significantly different from zero at the five percent level. There are two possible explanations for the consistency of these results. First, there would tend to be certain types of "economies of scale" when larger purchases are involved. Secondly, and perhaps most importantly, larger households tend to have a younger average age, and this characteristic would tend to be inversely correlated with per capita consumption of seafood. This is underscored by the finding that the only species for which 'size' was not a significant variable were Clams/Oysters and Scallops. For these two species, the aggregate equations were selected. Thus, the 'family size' variable was only related to the number of people in each income group for a given region; average age was not inversely correlated with the size of the group as it was to family size on a household level. Therefore, the age distribution effect is lost in these instances.

The variables measuring the impact of religion present results which are almost uniform: with but two exceptions, religion does not appear to be a significant explanatory variable in the consumption of seafood.[10] The two species for which religious affiliation was important are Groundfish and Tuna. For Groundfish, for example, the per capita annual consumption for a Catholic household was higher by 89 cents. For Tuna, the coefficinet on Jewish religious affiliation was positive and significant. The species for which the impact of regional differences in consumption were significant consisted of (1) Lobsters, (2) Oysters/Clams, (3) Scallops. However, for the most part, the importance of regional 'taste' conformed to expectations in the sense that the three species listed above have pronounced regional patterns of consumption. The species with a fairly large national market, e.g., Shrimp, Tuna, etc. did not exhibit strong regional tendencies.

B. Economic Variables

The results with respect to the economic variables are mixed. The income coefficients for several of the shellfish categories were positive and significant at the five percent level. This group includes the income parameters on Crabs, Lobsters, and Shrimp. Only one of the finfish categories was positive and significant, and that was Tuna. Salmon, on the other hand, had a negative sign and was also significant, while Groundfish, Oysters/Clams, and Scallops

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[10] This is consitent with the findings of F.W. Bell in "The Pope and the Price of Fish," American Economic Review, 58: 1346-1350.

were positive but nonsignificant.[11] Thus, of the eight species income parameters, four were significantly different from zero and positive, one was negative and significant, and three were positive but insignificantly different from zero. Given these findings, it is not at all surprising that, in attempting to measure the importance of income on the marginal consumption of all seafood, we found only a marginally significant parameter in chapter 3.[12] The point is that for certain components, or types of seafood, income -- or aggregate expenditures -- is a fairly powerful explanatory variable, even though it is relatively unimportant for all seafood expenditures. One of the interesting features of the income coefficients is that the sum of the species parameters is not very far from the control total for all seafood: whereas the time series expenditures parameter is

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[11] These results are, with the exception of Groundfish, generally consistent with the time series results. See The Future of the World's Fishery Resources . . . by F.W. Bell, D.A. Nash, E.W. Carlson, F.V. Waugh, Richard Kinoshita, and Richard F. Fullenbaum (in manuscript form). A possible explanation for the difference in Groundfish between cross-section and time series estimates may lie in the fact that the time series results are picking up exogenous trends correlated with increases in per capita income. Thus, the 'true' 'long-run' income estimate may be insignificantly different from zero.

[12] Some studies have shown a higher income elasticity for Shellfish than for all seafood. This is consistent with our results. For example, the income elasticity for all seafood is equal to .292, while the income elasticity for Crabs is equal to .541, and the income elasticity for Lobsters is equal to 1.84.

equal to .002032, the sum of the cross-sectional income coefficients is equal to .00197595.[13] In one sense, this makes the method of constraining these parameters to the time series seafood expenditure coefficient a relatively insignificant matter. There is no *a priori* reason why this necessarily would have been the case; but, given that our results from the cross-sectional equations came reasonably close to the control total, the method of constraining the individual income coefficients discussed in chapter two is unconsequential compared to some other method. In other words, the cross-sectional parameters will not be changed substantially if some other method of distributing or constraining individual species coefficients is used.

Our discussion of the price parameters may be subdivided between the own price expenditure derivatives and the cross price expenditure partials. In six out of eight cases, a_{ii} was greater than zero. Given the necessary condition that $\frac{\partial x_i}{\partial p_i} < 0$, this implies a price elasticity less than one. However, for these six coefficients, only three were significantly different from zero: Groundfish, Crabs, and Salmon. Two species had negative coefficients, implying a price elasticity greater than one: Lobsters and Salmon.

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[13] The difference between the control total and the sum of the cross-sectional income coefficients would be greater if such inferior seafood commodities such as sardines were included. With their inclusion the major difference would then be accounted for by the fact that the control total was a parameter on total spending, while the cross-sectional estimates were parameters on total income.

However, only Salmon had a significant coefficient (at the 10 percent level). The number of species which display price inelasticity is not inconsistent with some of the time series findings.[14]

The estimates of the 'unrestricted' cross partial expenditure derivatives in a few cases gave some surprisingly significant results. However, while several of the parameters were insignificant at the five percent level, a sufficient number were significant at least at the ten to fifteen percent level so that the required number of 'reliable' independent estimates could be obtained within the context of the 'restricted' procedure. The reason that we have extended the level of significance is that <u>for cross partial estimates</u> among such disaggregated commodity grouping power is more <u>important than significance</u>. Altogether, there were thirty-one cross partial estimates which were significantly different from zero at the .15 level, twenty-three at the .10 level, and fifteen at the .05 level.

Several of the estimates were unexpectedly negative. Among the significant shellfish parameters, the cross partial between Crabs (quantity) and Shrimp (price), Lobster (quantity) and Shrimp (price, and Lobster (quantity) and Crabs (price) all fall into this category. On the other

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[14] For example, see the study by Suttor (35) and Waugh (41).

hand, the cross partial between Salmon and Tuna was positive and fulfilled our a priori expectations.[15] There were other species for which little past empirical evidence would give us any reason for suspecting substitutability or complementarity. The only reason for expecting the former is because of the disaggregated nature of the products. For example, the Shrimp-Tuna cross partial was positive and significant at the .15 level, the Groundfish-Oysters/Clams price coefficient was positive and significant at the .05 level, while on the other hand the Salmon-Crab cross partial was negative and significant at the .05 level.

In summary, the unrestricted estimates displayed a surprising degree of complementarity and not the substitutability we expected. However, several of the negative parameters are consistent with time series results, both for seafood products and for price effects between other food products.[16] It should be remembered that these are "gross" cross partials,

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[15] In some preliminary time series studies, the cross elasticity between Tuna (quantity) and Salmon was found to be positive and significantly different from zero for the 1930-1950 period. However, for later years (1950-1965) the same estimate was found to be positive but insignificantly different from zero. This conforms to our results in the sense that while the cross partial between Salmon (quantity) and Tuna (price) was positive and significant, the cross partial between Tuna (quantity) and Salmon (price) was positive but insignificantly different from zero at the ten percent level.

[16] Court, in his restricted least squares routine found a negative cross elasticity between mutton and pigmeat. At the same time, some preliminary time series runs for Shellfish have also obtained negative cross elasticities; e.g., between Lobsters and Shrimp, etc.

as opposed to income compensated coefficients. Nonetheless, because income effects in these instances are negligible, it follows that, in general, the gross partial derivatives will reflect the sign of the income compensated parameters.

5. Formulation of the Price Derivatives in a General Equilibrium Framework

In this section we shall implement the method outlined in chapter two for obtaining all of the price derivatives consistent within a utility-maximization framework. Table 4.9 presents the twenty cross partial estimates which were selected for our general equilibrium analysis. The general criterion for selection was based upon the t ratios of the parameters. Of the twenty estimates, seventeen were picked from the group which had the highest t ratios.[17] When a_{ij} and a_{ji} were both significant for a given i and j, the more significant parameter was generally chosen.[18]

Given the set of eight a_{ii}, twenty a_{ij}, and eight income coefficients b_i, the following procedure was used.

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[17] The reason for inclusion of some non-significant estimates is related to deriving all of the elements of F^{-1}, and not incurring singularity in the p matrix. This is explained in detail in a later part of this section.

[18] An exception to this was the cross partial between Groundfish and Lobsters. Both a_{ij} and a_{ji} were significant at the .05 level, but opposite signs. We picked the positive cross partial even though it has a slightly lower t ratio because a substitute relationship made more sense, especially since the t ratios were so close in absolute value.

First, the eight income coefficients were constrained such that their total was equal to .002032. The difference between the restricted and unrestricted income parameters is negligible, as can be seen from Table (4.10).

Table 4.9

Selected Cross Partial Estimates

Equation	Cross Partials (Price of Species j)
1. Shrimp	Tuna, Salmon, Groundfish, Scallops
2. Crabs	Groundfish, Scallops, Oysters/Clams
3. Lobsters	Shrimp, Groundfish, Oysters/Clams
4. Tuna	Crabs, Scallops
5. Salmon	Crabs, Lobsters, Scallops, Oysters/Clams
6. Groundfish	Tuna, Oysters/Clams
7. Scallops	Lobsters
8. Oysters/Clams	Tuna

Table 4.10

	Unrestricted Income Parameters	Restricted Income Parameters
Shrimp	$5.72010105 \times 10^{-4}$	5.88231×10^{-4}
Crabs	1.5292862×10^{-4}	1.57265×10^{-4}
Lobsters	9.9434587×10^{-4}	1.02254×10^{-3}
Tuna	5.2064527×10^{-4}	5.3541×10^{-3}
Salmon	$-3.5369545 \times 10^{-4}$	-3.63725×10^{-4}
Groundfish	$4.82266183 \times 10^{-5}$	4.95942×10^{-5}
Scallops	2.21004×10^{-5}	2.27271×10^{-5}
Oysters/Clams	1.9404959×10^{-5}	1.99552×10^{-5}

All of the restricted income coefficients were deflated by the time series mean price index, $\bar{P}_f$, which is equal to

1.02412. Then, letting the ratio of a given species mean per capita expenditures to $\bar{p}_f$ equal $\bar{x}_i$, the quantity of the i^{th} species consumed, we can derive $\frac{\partial x_i}{\partial p_j}$ and $\frac{\partial x_i}{\partial p_i}$ in the following way:

$$(4.3) \quad \frac{\partial x_i}{\partial p_j} = \hat{a}_{ij}/\bar{p}_f$$

$$(4.4) \quad \frac{\partial x_i}{\partial p_i} = (\hat{a}_{ii} - \bar{x}_i)/\bar{p}_f$$

In this way, we can translate twenty-eight own and cross partial expenditure derivatives into twenty-eight own and cross partial price derivatives.

The next step involves taking advantage of the symmetry assumptions with respect to substitution effects in order to derive an additional twenty cross partial derivatives. That is, for the known cross partials we have,

$$(4.5) \quad \frac{\partial x_i}{\partial p_j} + \frac{\hat{b}_i}{\bar{p}_f} \bar{x}_j ,$$

which is equal to the substitution effect. Because of symmetry, we have,

$$(4.6) \quad \frac{\partial x_i}{\partial p_j} + \frac{\hat{b}_i}{\bar{p}_f} \bar{x}_j = \frac{\partial x_j}{\partial p_i} + \frac{\hat{b}_j}{\bar{p}_f} \bar{x}_i$$

Thus, we can obtain an additional twenty elements, expanding the number of known elements from twenty-eight to forty-eight.

Given that we have a matrix of substitution effects containing forty-eight elements, we may take our time series estimate $\hat{\gamma}$, equal to 1,030.3, and divide that estimate into all of the known elements. This gives us the appropriate elements of,

$$(4.7) \quad F^{-1} + F^{-1}p_F p_F' F^{-1}$$

Given that $-F^{-1}p_F$ is equal to the vector of restricted income parameters (column 2 in Table 4.10), we may form the matrix $F^{-1}p_F p_F' F^{-1}$ by performing the following operation,

$$(4.8) \quad (-F^{-1}p_F)(-F^{-1}p_F)' \equiv F^{-1}p_F p_F' F^{-1}$$

By performing the operation indicated on the left hand side of (4.8) we will obtain all of the elements on the right hand side of (4.8). Then, by subtracting the elements of (4.8) for which substitution effects are known, we derive forty-eight elements of the matrix F^{-1}. Thus, there are sixteen unknown elements of F^{-1}, of which we have only to solve for eight because of symmetry. Theoretically, we could arrive at the missing elements of F^{-1} by rearranging $-F^{-1}p_F$, so that there would be eight equations in eight unknowns.

However, there are some complications. Because of the relatively large order of F^{-1} it was possible to encounter the problem of singularity. That is, denoting the 8x1 vector of unknown elements of F^{-1} as Z", we may solve for that vector by first summing over individual products of the known elements of F^{-1} and prices, so that, for a given income coefficient, h_i, we can derive another element, h_i', by addition, i.e.,

$$(4.9) \quad h_i' = h_i + \sum_{j^*} \bar{F}_{ij} P_F$$

where $\bar{F}_{ij}$ is the i, j^{th} known element of F^{-1}, and there are, by assumption, j^* known elements in any given row. Then, it follows that an entire vector of known elements of the type depicted in (4.9), H_i' can be formed. The unknown elements of F^{-1} can be tied together through a matrix p, of order 8x8, which has elements equal to $\bar{p}_F$ (the time series mean) or zero.

Thus,

$$(4.10) \quad H_i' = PZ''$$

$$(4.11) \quad Z'' = P^{-1}H_i'$$

If p is singular, we cannot solve for Z". A sufficient condition for the nonsingularity of p in this instance is that for any two of the missing cross-partials, say, $\frac{\partial x_i}{\partial p_j}$ and $\frac{\partial x_i}{\partial p_m}$ $i \neq L$, and $j \neq M$. A necessary condition for the non-singularity of p is that <u>either</u> $i \neq L$ or $j \neq M$. It was precisely this consideration that prompted the inclusion of three relatively insignificant parameters for the set of independently known cross partials. In addition, it was necessary to make certain elements endogenous, or derived, even though they were fairly significant and would normally have been chosen as the exogenous elements.[19]

Given that $\bar{p}$ is equal to 1.02413, the matrix p and the vector H_i', are given as,

(4.12)

$$P = \left(\begin{array}{cccccc} 0 & 1.02413 & 0 & 0 & 0 & 0 \\ 1.02413 & 0 & 1.02413 & 0 & 0 & 0 \\ 0 & 1.02413 & 0 & 1.02413 & 0 & 0 \\ 0 & 0 & 1.02413 & 0 & 1.02413 & 0 \\ 0 & 0 & 0 & 1.02413 & 0 & 1.02413 \\ 0 & 0 & 0 & 0 & 1.02413 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.02413 \\ 1.02413 & 0 & 0 & 0 & 0 & 0 \end{array} \right.$$

$$\left. \begin{array}{cc} 0 & 1.02413 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 1.02413 & 0 \\ 0 & 1.02413 \\ 1.02413 & 0 \end{array} \right)$$

(4.13)

$$H_i' = \begin{pmatrix} -.0110465 \\ -7.35699\times10^{-4} \\ -.00220943 \\ .00326402 \\ -.00261959 \\ .00733684 \\ .00605266 \\ .00972057 \end{pmatrix}$$

After solving for Z", and multiplying by -1, we can find all of the elements of F^{-1}. After addition of $F^{-1}p_Fp_F'F^{-1}$, and multiplication by $\hat{\lambda}$, the entire substitution matrix may be obtained, i.e., $\hat{\lambda}\,[F^{-1}+F^{-1}p_Fp_F'F^{-1}]$. The matrix

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[19]For example, the cross partial between the quantity of Salmon and the price of Tuna was positive and significant at the .05 level. However, this was eliminated as a known element in order to solve for the missing elements of F^{-1}. However, this type of phenomenon was minimized. It should also be noted that after being 'solved' the sign of this cross partial was still positive.

of substitution effects and the matrix of own and cross partial derivatives -- inclusive of income effects -- are presented in Tables 4.11 and 4.12 respectively. Table 4.13A shows the price elasticities consistent with these restricted estimates, for the bundle $\bar{x}_i$ and for the time series price index $\bar{p}_f$. In addition, supplemental Table 4.13B presents some possible explanations for some of the questionable estimates.[20] In terms of the missing elements, the following qualitative results -- in terms of sign -- were obtained:

Quantity	Price: Crabs	Lobsters	Tuna	Salmon
Shrimp	-			
Crabs		+		
Lobsters			+	
Tuna				+

Quantity	Price: Groundfish	Scallops	O/C	Shrimp
Salmon	-			
Groundfish		+		
Scallops			-	
Oysters/ Clams				+

Another set of estimates which may be derived from the restricted parameters is the elasticity of substitution between commodities. The latter is defined as,

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[20] We would not expect all of the estimates to be completely reasonable, especially when there are so many parameters involved. However, the useful aspect of this framework is that if better estimates for the initial set of twenty cross partial derivatives are obtained, another set of derived parameters can be computed, and a comparison can be made.

Table 4.11

MATRIX OF SUBSTITUTION EFFECTS

Price of Species j

Quantity of Species i	Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/ Clams
Shrimp	- 2.42817	-13.1687	-10.0872	1.26434	- 1.92511	- .338838	1.82519	5.24731
Crabs	-13.1687	- .138761	1.09809	-1.18895	- 2.53176	.879372	1.45636	2.39562
Lobsters	-10.0872	1.09809	- 2.28779	12.143	- 1.48086	7.10357	.0631106	3.46332
Tuna	1.26434	- 1.18895	12.143	-2.13379	1.12462	.331929	2.55043	1.93449
Salmon	- 1.92511	- 2.53176	- 1.48086	1.12462	- .273365	-15.4262	2.55616	1.37634
Ground-fish	- .338833	.879372	7.10357	.331929	-15.4262	- 1.75351	1.51056	1.10992
Scallops	1.82519	1.45636	.0631106	2.55043	2.55616	1.51056	- .617979	-11.8038
Oysters/ Clams	5.24731	2.39562	3.46332	1.93449	1.37634	1.10992	-11.8038	- .520134

Table 4.12

MATRIX OF PRICE DERIVATIVES

Quantity of Species i	Price of Species j							
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/Clams
Shrimp	-2.4298	-13.169	-10.0877	1.26227	-1.92637	-.340028	1.82501	5.24696
Crabs	-13.1691	-.13884	1.09795	-1.1895	-2.5321	.879053	1.45631	2.39553
Lobsters	-10.0901	1.09757	-2.28869	12.1394	-1.48304	7.10149	.0627888	3.46271
Tuna	1.26285	-1.18922	12.1425	-2.13568	1.12347	.330842	2.55027	1.93417
Salmon	-1.9241	-2.53158	-1.48053	1.1259	-.272588	-15.4254	2.55627	1.37656
Ground-fish	-.338971	.879347	7.10353	.331754	-15.4263	-1.75361	1.51055	1.10989
Scallops	1.82513	1.45635	.0630904	2.55035	2.55611	1.51052	-.617987	-11.8038
Oysters/Clams	5.24726	2.39561	3.4633	1.93442	1.3763	1.10988	-11.8038	-.520146

Table 4.13A

MATRIX OF PRICE ELASTICITIES *

Quantity of Species i	Price of Species j: Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/ Clams
Shrimp	-.852202	-4.61876	-3.53805	.442715	-.675635	-.119258	.640085	1.84026
Crabs	-25.4469	-.268283	2.12159	-2.2985	-4.89283	1.69861	2.81406	4.62893
Lobsters	-11.1114	1.20866	-2.52034	13.3681	-1.63315	7.82027	.069144	3.81319
Tuna	.349547	-.329166	3.36095	-.591139	.310967	9.15744×10^{-2}	.705894	.535363
Salmon	-.8797	-1.15744	-.6769	.514762	-.124627	-7.05251	1.16873	.629364
Ground-fish	-.162981	.422801	3.41546	.159511	-7.41715	-.843157	.726291	.533649
Scallops	5.66415	4.51967	.195796	7.91482	7.93269	4.68778	-1.91788	-36.6322
Oysters/ Clams	8.52996	3.89431	5.62995	3.1446	2.23732	1.80422	-19.1883	-.845551

* Footnotes are explained in Supplemental Table 4.13B.

Supplementary Table 4.13B

Notes to Table 4.13A

[1]This may reflect complementarity to the extent that Crabs and Shrimp, Lobsters and Shrimp are eaten together in one 'set', particularly with respect to consumption away from home. These items did exhibit a very high degree of away from home consumption relative to total consumption. In addition, complementarity among these species is consistent with some of the time series results.

[2]In these cases, we may have the same type of phenomenon as was reflected in note 1. However, because there are lower levels of per capita consumption for Lobsters and Crabs relative to Shrimp the corresponding cross elasticity is much more negative.

[3]While Lobsters are primarily eaten away from home, Tuna is principally consumed at home. Substitutability is therefore likely to the extent that for some food products home away-from-home consumption compete for consumers' dollars. However, it is unlikely that there is as high a degree of substitutability as is indicated by our estimated cross elasticity. The same is true of Lobsters and Groundfish.

[4]Groundfish and Salmon are primarily consumed at home. Complementarity in this case is doubtful.

[5]Scallops and Oysters/Clams are eaten together, but the high degree of complementarity indicated here is doubtful. These are perhaps the weakest estimates.

(4.14) $\sigma_{ij} = K_{ij}\bar{m}/(\bar{x}_i\bar{x}_j)$

where K_{ij} is the substitution effect, $\bar{x}_i$ and $\bar{x}_j$ have previously been defined, and $\bar{m}$ is mean per capita total spending. Unfortunately, we have no observations on total per capita spending from the cross-sectional study, and so the time series estimate of mean per capita aggregate expenditures was used. Given that estimates from both the time series and cross sectional studies were mixed, the application of $\bar{m}$ from the time series will not affect results substantially. Table 4.14 presents the partial cross elasticities of substitution.

6. Conclusions

In summary, we have, subject to certain constraints, selected the best estimates available for the cross partial derivatives between different species of seafood. We have derived all of the other cross partial derivatives by assuming (1) a continuously differentiable utility function, (2) additivity in the utility function between seafood and all other commodities (including the commodity "all other food"), and (3) that the $\frac{\partial \lambda}{\partial y} = -1$. The latter is not inconsistent with the uniqueness of the utility function up to a positive monotonic transformation. In the process, we have solved for a "linearized" substitution matrix, and an elasticity of substitution matrix.

Table 4.14

MATRIX OF ELASTICITIES OF SUBSTITUTION

j

Quantity of Species i	Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/Clams
Shrimp	-545.534	-16300.2	-7115.63	224.175	-563.81	-104.359	3628.44	5464.14
Crabs	-16300.2	-946.29	4267.64	-1161.43	-4085.14	1492.2	15951.	13743.9
Lobsters	-7115.63	4267.64	-5067.09	6760.05	-1361.73	6869.46	393.925	11323.4
Tuna	224.175	-1161.43	6760.05	-298.577	259.935	80.6812	4001.35	1589.76
Salmon	-563.81	-4085.14	-1361.73	259.935	-104.365	-6193.55	6624.22	1868.3
Ground-fish	-104.359	1492.2	6869.46	80.6812	-6193.55	-740.385	4116.73	1584.46
Scallops	3628.44	15951.	393.925	4001.35	6624.22	4116.73	-10870.6	-108762.
Oysters/Clams	5464.14	13743.9	11323.4	1589.76	1868.3	1584.46	-108762.	-2510.4

Two further questions relate to (1) the relative impact of a change in all seafood prices upon individual species expenditures, and (2) an attempt to use the own and cross price partial derivatives to backcast expenditure changes. In order to answer both questions the linear expenditure coefficients consistent with the price derivatives obtained via the utility maximization procedure must first be computed. These are given in Table 4.15.

Assume that all seafood prices are increased by ten percent. By taking Table 4.15 and postmultiplying by a vector of price changes (where all elements are equal to .1) we get the change in per capita expenditures:

	Change in Expenditures ($)
Shrimp	-1.72
Crabs	-1.09
Lobsters	1.11
Tuna	2.00
Salmon	-1.47
Groundfish	- .46
Scallops	- .21
Oysters/Clams	.39

What is important is the change in expenditures for one species relative to another. In terms of negative changes in per capita expenditures, Shrimp appears to be most sensitive, and Tuna would appear to be least sensitive to a general change in prices in the seafood sector.

Table 4.15

MATRIX OF LINEAR PRICE COEFFICIENTS (RESTRICTED)

Expenditures of Species i	Price of Species j							
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/ Clams
Shrimp	.362769	-13.4868	-10.3311	1.29273	-1.97285	-.348233	1.86905	5.37357
Crabs	-13.4869	.375322	1.12444	-1.2182	-2.5932	.900265	1.49145	2.45333
Lobsters	-10.3336	1.12405	-1.43583	12.4323	-1.51883	7.27285	6.43039×10^{-2}	3.54627
Tuna	1.29332	-1.21792	12.4355	1.42561	1.15058	.338825	2.61181	1.98084
Salmon	-1.97053	-2.59267	-1.51626	1.15307	1.90806	-15.7976	2.61795	1.40978
Groundfish	-.34715	.900566	7.27494	.339759	-15.7985	.283889	1.547	1.13667
Scallops	1.86917	1.49149	6.46128×10^{-2}	2.61189	2.61779	1.54697	-.310674	-12.0886
Oysters/ Clams	5.37388	2.45342	3.54687	1.9811	1.40951	1.13666	-12.0886	8.24592×10^{-2}

The second major question concerns the ability of the estimates to explain past behavior of real expenditure changes in relation to changes in relative prices. Unfortunately, only the most general sort of approximations are available for individual species retail prices and retail expenditures.[21] For that reason, we will use the derived parameters only to see if they predict the change in direction implied by the data available. Between 1955 and 1967, the estimated percentage change in real prices were as follows: Shrimp, 24%; Crabs, -8%; Lobsters, 58%; Tuna -24%, Salmon, 7%; Groundfish, 17%; Scallops, 1%; Oysters/Clams, 24%. If Table 4.15 is postmultiplied by this vector, and then any changes induced by increases in real income are added, we can compare the computed change in expenditures with changes implied by the data to see if the change of direction in expenditures are the same. Accordingly, we have,

	Actual Change in Real Expenditure	Predicted Change in Real Expenditure
Shrimp	+	-
Crabs	+	-
Lobsters	+	+
Tuna	+	+
Salmon	-	-
Groundfish	+	-
Scallops	-	-
Oysters/Clams	+	+

[21] These approximations are based upon National Marine Fisheries Service estimates of trade margins and per capita consumption in terms of edible weight.

In five out of eight cases, our estimates predict correctly in terms of direction of change. However, it must be remembered that, except for the naive treatment of time trends for all seafood presented in chapter three, and the time trend to be employed for forecasting purposes in chapter five, we have not really dealt in detail with changes in consumers' taste with respect to individual species. Over the thirteen observation periods, it is very likely that dynamic changes in consumers' taste were affecting relative consumption patterns, especially for very disaggregated commodities. In addition, the reliability of the data that was used -- both for measuring changes in relative retail prices and for estimating changes in per capita expenditures -- cannot be considered unquestionable. Judged in the light of these inherent problems, the estimated price derivatives did not really do that badly in a 'backcasting' framework.

CHAPTER V

THE FORECAST AND THE INTRODUCTION OF SUPPLY CONSTRAINTS

1. Introduction

The basic purpose of this study has now been completed. We have gained insight into some previously unidentified demand parameters. Some of the results were surprising, especially those for which we had expected substitutability, but instead found a degree of complementarity. Better estimates may yet reject some of the qualitative results we have derived. Nonetheless, using all of the parameters we have obtained in a general equilibrium context may help to shed some light on some rather important policy questions - questions that have traditionally been handled in a partial equilibrium setting. However, in order to extend the scope of the analysis to a policy oriented framework, we must first develop appropriate forecasts of seafood consumption, and identify supply constraints for the relevant subsectors of the fishing industry. Accordingly, this chapter bridges the gap between the empirical research and policy application by providing the following information: (1) a projection of consumer expenditures for the seafood category at constant prices; (2) a distribution of the projected seafood expenditures across the eight species that were developed in chapter four and which constitute practically all seafood consumed (by value) in the United States; (3) a summary of available data on maximum sustainable yield; (4) the selection of species that are to be placed into the "constrained" subsectors and those that are to be categorized as the "unconstrained" species; (5) the establishment of effective supply constraints for species in the constrained subsectors; (6) the additional assumptions necessary to relate the level of projected expenditures (expressed in dollars) to the biological constraints (expressed in weight); and (7) the estimation of the difference between projected consumption at a given price and attainable consumption for the constrained species. The latter, in essence, represents the final outcome of all of the previous six steps, and is, therefore, tied to the assumptions made in these 'building blocks'. To that extent, the vector of differences estimated in (7) are hypothetical.[1] Another qualification concerns the application which will be considered in chapter six. That is, it is the usual case that prices are given, i.e. exogenous, and quantity adjustments are derived from the own and cross partial price derivatives. However, in the policy application of the next chapter, quantity adjustments are given - equal to the vector of the differences between attainable consumption and projected consumption - and a set of price changes is obtained consistent with those quantity adjustments. This is a valid procedure only to the extent to which market clearance at some predefined level is a fairly reasonable assumption.

2. The Forecast

The forecast of total seafood expenditures is given at mean price levels, so that the predicting equation becomes,

$$(5.1) \quad v_{ft} = \bar{v}_f + b_f u_t + c_f t.$$

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[1] It is even possible that the vector of differences would not contain negative elements. This would not invalidate the policy prescriptions but merely tend to reduce the extent of the problem, i.e. the degree of redundant input usage. In that case, the forecasting model would be significant because it is the type of forecast used - consistent with the behavior of other commodities - that would account for this type of phenomenon.

Given the parameters obtained in chapter three, (5.1) reduces to:

$$(5.2) \quad v_{ft} = 12.49 + .002032\, u_t - .067010t$$

In order to determine v_{ft}, we must first have a set of projected levels of aggregate per capita expenditures as well as a series on expected population for the United States. These are provided in Table 5.1. The projection of u_t, at mean price levels, is equal to the difference between forecasted per capita aggregate expenditures and mean per capita expenditures during the period in which the parameters were estimated, i.e.,

$$(5.3) \quad u_t = m_t - \sum_{j=1}^{k} \bar{\bar{p}}_j \bar{\bar{x}}_j \equiv m_t - \sum \bar{v}_j \equiv m_t - \bar{m}$$

Table 5.2 presents the forecast for per capita seafood expenditures for the years 1975, 1980, 1985, 1990, and 2000, in nominal terms and in real terms. In addition, these expenditures are distributed among species on the basis of the modified cross-sectional income coefficients, and according to how the constant in (5.2), 12.49, is broken down among species. Because of sparse information on consumer expenditures for individual species, we do not have a continuous time series on that disaggregated a basis. However, we do have some estimates with respect to how the mean level of expenditures on seafood during the 1952-1967 period may have been distributed.[2]

Given that the coefficient on time is equally divided between species (by assumption), each of the forecasting equations for the eight species is as follows:

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2 This was provided by the National Marine Fisheries Service via some work on trade margins on individual seafood products.

Table 5.1

PROJECTED EXPENDITURES AND POPULATION FOR THE UNITED STATES

Year	Population (millions)[1]	Personal Per Capita Disposable Income ($)[2]	Personal Per Capita Expenditures ($) *
1975	219.4	3,036	2779.76
1980	235.2	3,555	3254.96
1985	252.9	4,049	3707.26
1990	270.8	4,574	4187.95
2000	307.8	6,091	5576.92

* Derived by multiplying the projected level of personal per capita disposable income by the average ratio of personal per capita expenditures to personal per capita disposable income during the 1952-1967 period.

1 Series C, U.S. Department of Commerce, Bureau of the Census

2 National Planning Association Center for Economic Projections, with extrapolation for later years.

Table 5.2

Vector of Per Capita Seafood Expenditures

Year	
1975	13.3648
1980	13.9984
1985	14.5855
1990	15.2302
2000	17.3886

Deflated Vector of Per Capita Seafood Expenditures

Year	
1975	13.0494
1980	13.668
1985	14.2413
1990	14.8708
2000	16.9783

Shrimp

$$(5.4)\quad v_t = 3.13 + .000588231u_t - .0083t$$

Crabs

$$(5.5)\quad v_t = .59 + .000157265u_t - .0083t$$

Lobsters

$$(5.6)\quad v_t = .93 + .00102254u_t$$

Tuna

$$(5.7)\quad v_t = 2.13 + .0005354lu_t - .0083t$$

Salmon

$$(5.8)\quad v_t = 2.82 - .000363726u_t - .0083t$$

Groundfish

$$(5.9)\quad v_t = 1.56 + .0000495942u_t - .0083t$$

Scallops

$$(5.10)\quad v_t = .41 + .0000227271u_t - .0083t$$

Oysters/Clams

$$(5.11)\quad v_t = .92 + .0000199552u_t - .0083t$$

Tables 5.3 and 5.4 present the matrix of nominal and real projected seafood expenditures by species, respectively. It is important to note that, at the margin, several of the shellfish categories have relatively high increases in per capita consumption, while the finfish categories -- with the exception of tuna -- have relatively low rates of increase in consumption.

3. Supply Constraints

The establishment of effective supply constraints requires knowledge of maximum sustainable yield for the species relevant to consumption in the United States. Table 5.5 presents a summary of current estimates,

Table 5.3

MATRIX OF FORECASTED PER CAPITA SEAFOOD EXPENDITURE

Year	Species							
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Groundfish	Scallops	Oysters & Clams
1975	3.55799	.607129	1.77204	2.50763	2.34044	1.47448	.298867	.806224
1980	3.79602	.640361	2.21645	2.72056	2.1261	1.45655	.268167	.774207
1985	4.02057	.669992	2.63744	2.92123	1.92009	1.43748	.236946	.741733
1990	4.26183	.704088	3.08747	3.13709	1.70375	1.41982	.206371	.709825
2000	4.99587	.839524	4.42475	3.79776	1.11555	1.4057	.154938	.654542

Table 5.4

DEFLATED MATRIX OF FORECASTED PER CAPITA SEAFOOD EXPENDITURES

Year	Species							
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Groundfish	Scallops	Oysters & Clams
1975	3.47402	.5928	1.73022	2.44845	2.28521	1.43968	.291814	.787197
1980	3.70643	.625248	2.16414	2.65635	2.07592	1.42217	.261838	.755936
1985	3.92569	.65418	2.5752	2.85228	1.87477	1.40355	.231354	.724228
1990	4.16125	.687471	3.0146	3.06306	1.66354	1.38631	.201501	.693073
2000	4.87796	.819711	4.32032	3.70813	1.08922	1.37253	.151282	.639095

Table 5.5

World Maximum Sustainable Yield and United States Share of MSY for Selected Fisheries
(Live Weight)

Species	MSY[1] (Thousand Metric Tons)	United States Share[2]
Shrimp	1,491.9	.274
Crabs	671.5	.275
Lobsters	192.5	1.000[3]
Tuna	2,570.0[4]	.274
Salmon	484.4	.245
Groundfish	9,173.6	.082
Scallops[5]	1,490.9	.79
Oysters/Clams[6]	--	--

[1]Source: J.A. Gulland, Area Reviews on Living Resources of the World's Ocean, Food and Agricultural Organization of the United Nations, Indicative World Plan for Agricultural Development.

[2]Unless otherwise noted, the general procedure for deriving the United States share was as follows: Let y_{ij} denote the share of consumption out of total world landings of the i^{th} species by the j^{th} country. Letting t stand for time, we may specify the following equation:

$$\text{(5.5.1)} \quad \log y_{ij} = \alpha + \beta \frac{i'}{t.}$$

Once $\hat{\alpha}, \hat{\beta}$ are obtained, the long-run share, i.e., the share which (5.5.1) approaches as $t \to \infty$, is equal to the antilog of $\hat{\alpha}$.

[3]The share of 1.000 was established for lobsters because the United States had the overwhelming share of world landings because of the location of the resource, and, it was felt, 1.000 was a more realistic share. (5.5.1) was run and yielded a share of about .85.

[4]Includes the potential maximum sustainable yield of Central Pacific Skipjack, estimated at 800,000 metric tons.

[5]Includes the recently discovered calico scallop resource found off the eastern coast of the U.S.

[6]An MSY for Oysters/Clams is not a relevant concept because of the development of artificial techniques of cultivation.

as well as an assumed long-run share which represents the proportion of MSY which the United States will consume.[3] This last assumption is made for two reasons: (1) in order to abstract from international trade considerations; (2) in order to avoid problems concerning international competition for a fixed resource.

The only task that remains involves the categorization of species under the heading of 'constrained' or 'unconstrained.' Most of the species covered in this study fall into the constrained subsector category. That is, the ratio of landings to maximum sustainable yield for these species is such that the attainment of MSY is a reasonable outcome in the foreseeable future.[4] The following species can be classified under this heading: Shrimp, Crabs, Lobsters, Tuna, Salmon, and Groundfish. On the other hand, the unconstrained species are those for which the difference between long-run average cost and long-run marginal cost is either negligible, or, does not exist by definition. The only example of the latter is Oysters/Clams. This species can be treated as an ordinary commodity in the sense that a perfectly elastic supply function is not unreasonable because of the development of artificial techniques of cultivation.[5] The only example of the former is

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[3] For an explanation of the derivation of these shares, see Table 5.5.

[4] See Appendix C for a formal derivation of the long-run supply curve and the role which the ratio of landings to maximum sustainable yield assumes in determining the slope of the supply function.

[5] For a thorough discussion of this, see "Molluscan Resources", by A. C. Simpson, in, <u>Area Reviews on Living Resources of the World's Ocean</u>, F.A.O. Indicative World Plan for Agricultural Development, Fisheries Laboratory, Burnham-on-Crounch, 1969.

scallops, which is so relatively underutilized that a perfectly elastic supply function -- even in a long-run setting -- is a fairly good approximation.

In conclusion, there will be six species in the constrained subsector category and two in the unconstrained category.

4. Additional Assumptions

The only additional assumption needed in order to tie together the biological constraints and the projected level of seafood expenditures concerns a given level of weight per dollar consumed for each species. More specifically, we shall assume that forecasting real expenditures on seafood is equivalent to holding the ratio of weight per capita consumed to the number of dollars per capita consumed, by species, constant. In other words, we will take the ratio of (1) mean per capita consumption (in weight) for the 1952-1967 period to (2) the mean per capita expenditures over the same period for each species, so that for any given level of projected real expenditures we may associate a given weight per capita consumed with that level of expenditures. This assumption is not such an unrealistic one in the sense that changes in prices in seafood consumption are also reflected, in general, in changes in weight consumed per dollar consumed. Given that quality changes are minimal in the seafood sector over time, and, given that our estimates of seafood expenditures take out the influence of other food consumption, then a high correlation between changes in price and changes in weight per dollar consumed is likely.[6] Thus, forecasting at constant prices reduces to forecasting at constant weight per dollar consumed.

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[6]Some preliminary correlations show a simple correlation coefficient of between .8 and .9 between changes in the seafood price index and dollars/weight for all seafood.

Table 5.6

PER CAPITA CONSUMPTION IN POUNDS

Year	Species							
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Groundfish	Scallops	Oysters & Clams
1975	1.15511	.185843	.245691	2.09563	3.13142	2.19048	.0236369	4.80978
1980	1.23239	.196015	.307308	2.27357	2.84464	2.16384	.0212089	4.61877
1985	1.30529	.205085	.365678	2.44127	2.569	2.13551	.0187397	4.42503
1990	1.38362	.215522	.428074	2.62167	2.27955	2.10927	.0163215	4.23468
2000	1.62192	.256979	.613486	3.17379	1.49256	2.0883	.0122538	3.90487

MATRIX OF MAXIMUM ATTAINABLE CONSUMPTION MINUS PROJECTED PER CAPITA CONSUMPTION (IN POUNDS)

1975	.42466	.123477	.445047	1.67391	-2.927334	-.30081
1980	.24125	.092526	.337029	1.242274	-2.654264	-.40111
1985	.06522	.063261	.233563	.82894	-2.391948	-.49615
1990	-.10370	.035086	.131557	.43238	-2.114201	-.57827
2000	-.49586	-.036496	-.121127	-.48686	-1.347087	-.74187

5. Conclusions

Table 5.6 presents (1) the projected consumption of per capita weight by species for the years 1975-2000, and (2) for the six species in the constrained subsector, the differential between projected consumption and the effective supply constraint for the years concerned. Note that the constraints are in per capita terms. Given this information, we will be able to derive vectors denoting differences between projected and attainable consumption in dollars.[7]

In conclusion, the differences derived are to a large extent a reflection of the methods employed, particularly the type of forecasting device that was utilized. Table 5.6 reflects rather modest negative differences, and even here, these are not manifested until later years. The net implications of this will be discussed more fully in the next chapter.

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7 See chapter six.

CHAPTER VI

POLICY IMPLICATIONS

1. Introduction

Thus far, the principal empirical findings have been oriented toward (1) the estimation of demand parameters and (2) the identification of effective supply constraints. We have not investigated the general shape of the transformation function between species, nor have we delved into the growth of the transformation locus over time. Rather, the emphasis has been placed upon a situation in which the general shape of the transformation curve is predefined for two reasons. The first reason is related to the assumption that the level of output for the constrained species is at least in the neighborhood of maximum sustainable yield. The second reason is that maximum yield will be maintained into perpetuity,[1]

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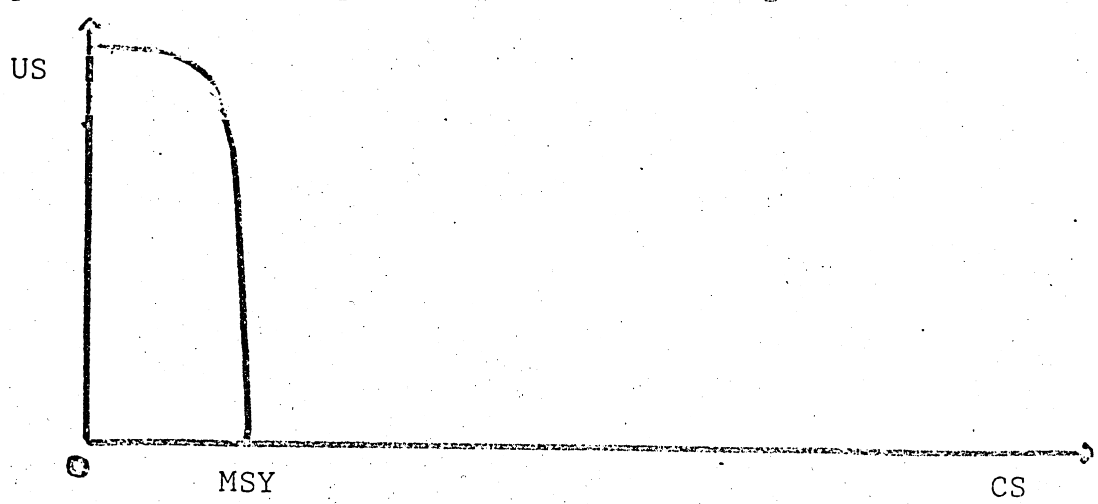
[1] Diagrammatically, this means that the transformation function between the constrained species and the unconstrained species will be depicted by the following:



i.e., the long-run supply function is perfectly inelastic at MSY. Any one of three conditions will practically ensure that this is the case. That is, if the biological function is such that increases in effort neither increase nor decrease yield, or, if the production function is one which exhibits nonconstant returns with respect to increases in the number of vessels, or, finally, if institutional pressures are forthcoming via a quota to maintain output at maximum yield, then perfect inelasticity is a fairly good approximation.

The only other critical assumption in our analysis is that the target levels of output in the unconstrained subsectors, i.e., the levels determined by the "constant utility locus," are technically feasible with the given level of resources in the fishing sector at a particular point in the future.[2] The realism of this assumption depends in

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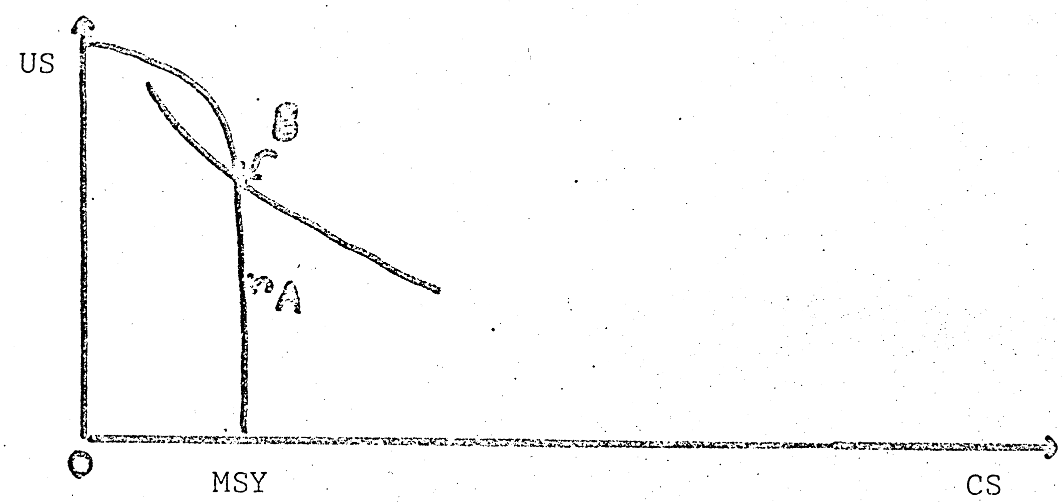
[2] In graphical terms, this implies that there are enough redundancies to insure that point B below is attained from an initial point, say, A.



large measure on the difference between the market solution and the solution obtained by the income compensated price derivatives. That is, if the difference is so great that a large degree of reallocation is implied, then increases in output in the unconstrained subsectors could probably not be effected without a decline in output in the constrained subsectors. On the other hand, we may obtain a difference which is so small that the reallocation implied is of the second order of smalls. Indeed, whether the difference is large or small is precisely what will be determined in our policy implications section.

It should also be remembered that the application considered does not involve the allocation of resources from the fishing industry to other sectors of the economy nor does it involve the maximization of the value product of all factors among marine subsectors subject to the prior restriction of a given level of inputs. Indeed, in neither case would maximum yield constitute a solution. Our basic framework of analysis and policy discussion presupposes market clearance of MSY and a given level of total resources in the entire fishing sector. The point of view emphasizes a reallocation of economic resources among subsectors so that a "better" solution is effected. That solution in no way can be considered "best" either from an interindustry or intraindustry allocative point of view. In other words, allocative implications, to the extent that they are significant, will be restricted to alternatives within the fishing industry.

This chapter essentially applies all of the parameters estimated in the previous two chapters to the analytical framework outlined here and at the beginning of the study. Section two presents a formal derivation of the change in prices that will occur in the market among the constrained species, the quantity adjustments that will take place among the unconstrained species, a "constant utility locus" of quantity adjustments, and some estimates regarding the allocative significance -- in terms of the readjustment of capital and labor -- of the 'target' levels of output established for the unconstrained species; section three contains a brief discussion about policy implications; finally, section four presents some concluding remarks with respect to some of the shortcomings of the techniques and assumptions that have been utilized in this research.

2. Forecasting, Price Changes, and Allocative Significance

There are three important topics that will be discussed in this section. First, we shall evaluate the importance of the type of forecasting procedure that was used. Second, we will determine changes in prices (given the constraints derived in chapter five), and compare those changes with the type of price movements that would obtain in a partial equilibrium framework. Thirdly, we will discuss allocative implications.

As an example of how the present method tends to reduce increases in projected consumption, we can compare our forecast of a particular species, say Shrimp, with some other work currently being completed. In the Future of the World's Fishery Resources: Forecasts of Demand, Supply and Prices to the Year 2000 with a Discussion of Implications for Public Policy (in manuscript form -- forthcoming), the percentage increase in per capita shrimp consumption for the United States from 1970 to 1980 is equal to 25.6%. This increase reflects adjustments in prices, i.e., the percentage change would be even greater if relative prices were held constant. On the other hand, the percentage increase in real Shrimp expenditures in our analysis for the same period of time is equal to 12 percent. Thus, the rate of increase of demand using this technique is considerably diminished.[3]

The second topic concerns changes in prices. It should be remembered that we have initially set the prices of all species equal to one another and equal to the time series mean price index for all seafood. Given this base, what is derived is a change in the index for all of the six constrained species. Consequently, the change in the index divided by the original base will give us the percentage

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[3]The techniques used in The Future of the World's Fishery Resources are essentially single equation log-linear type of formulations. In addition, world price is determined through the interaction of the long-run supply function and world-wide demand. Thus, even though exact comparisons cannot be made, it is nonetheless obvious that without restrictions placed upon demand equations, forecasts would tend to give much higher estimates of future consumption.

change in actual prices. Thus, even though we do not have any direct observations on actual prices, we can still derive the percentage change in those prices.

In order to obtain the price changes for the constrained set, we must first derive the vector of differences between projected consumption and attainable consumption. Here, another important qualification should be mentioned. That is, all changes, whether they are price changes or quantity adjustments (for the unconstrained set), are evaluated relative to the initial set of prices. Given our assumption about a constant weight per dollar for each species, it follows that all price changes and quantity adjustments are computed for an assumed weight per dollar. In this way, quantity adjustments in the unconstrained set, initially measured in dollars, may be converted into weight.

We have already computed the difference between forecasted consumption and attainable consumption (for the five points in time from 1975 to 2000) in pounds. However, the differences must be converted into dollars. This can easily be done by dividing the elements of the matrix of differences computed in chapter five by the appropriate species weight per dollar factor. These 'dollar' differences are presented in Table 6.1 for all of the six constrained species for each of the five forecasted years.

It is obvious that, even in dollars, the differences in Table 6.1 are rather modest. Only for the year 2000 are the elements uniformly negative across the constrained

Table 6.1

MATRIX OF ATTAINABLE CONSUMPTION MINUS PER CAPITA CONSUMPTION (IN DOLLARS)

Year	Species					
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Groundfish
1975	1.27717	.393866	3.13413	1.95573	-2.13627	-.197706
1980	.725564	.295139	2.37344	1.45142	-1.93699	-.263628
1985	.19615	.201789	1.64481	.968501	-1.74557	-.326093
1990	-.31188	.111917	.926458	.505176	-1.54287	-.380066
2000	-1.49131	-.116415	-.853007	-.568828	-.98306	-.487591

species, and in sufficient magnitude,[4] that market clearance at maximum yield is reasonable. Therefore, using the vector of differences for this year, we can proceed with the logical implications which follow from integrating this information with the matrix of price derivatives obtained in chapter four. Denoting 1, 2, 3, 4, 5, 6, as the species Shrimp, Crabs, Lobsters, Tuna, Salmon, and Groundfish, respectively, we may take the submatrix of own and cross price partials between these constrained species, given as F_i^*, and the vector of the change in consumption, Δx_i

$$(6.1) \qquad \Delta x_i = \begin{pmatrix} -1.491310 \\ -.116415 \\ -.853007 \\ -.568828 \\ -.983062 \\ -.487591 \end{pmatrix}$$

and find the market clearing change in prices:

$$(6.2) \qquad \Delta p_i = (F_i^*)^{-1} \Delta x_i = \begin{array}{r} \left(\begin{array}{r} .0130343 \\ .140441 \\ -.0542646 \\ -.102811 \\ .00796539 \\ .0366187 \end{array}\right) \end{array} \begin{array}{l} \text{Shrimp (1)} \\ \text{Crabs (2)} \\ \text{Lobsters (3)} \\ \text{Tuna (4)} \\ \text{Salmon (5)} \\ \text{Groundfish (6)} \end{array}$$

Thus, the percentage change in actual price is equal to the following:

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[4] It should be remembered that these differences are in per capita terms.

$$(6.3) \quad (\Delta p_i)(1/p_i) = \begin{pmatrix} .0127272 \\ .137132 \\ -.052986 \\ -.100389 \\ .00777771 \\ .0357559 \end{pmatrix}$$

It is apparent, disregarding the two negative price changes,[5] that the importance of examining the resource constraint in a general equilibrium framework on the demand side is -- at the very least -- the low rate at which prices are expected to increase. The question then arises "how do these price changes compare with the historical experience?" Viewed historically, Lobster prices have not declined, but have increased rapidly. Therefore, the expected price decline given here is not a good indicator. On the other hand, real Tuna prices have declined considerably over the past sixteen years. Groundfish prices over the 1950-1968 period have risen a modest 3.9%. Salmon prices have risen 17% since 1955; however, since 1963 consumption has essentially been constrained to maximum sustainable yield and from 1963 to 1968, real Salmon prices have risen only 2.5%. Crab prices have actually declined during the entire 1955-1967 period,

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[5]The negative price changes occur because we have predefined the quantity changes. In other words, because of the combination of negative quantity adjustments, the set of price changes consistent with those quantity adjustments includes some negative elements.

although from 1961-1967 they increased approximately 16%. Finally, Shrimp prices have increased approximately 24% over the 1955-1967 period, but if the first two years of that period are excluded, the increase amounts to only 3%. The importance of these price movements is that with the exception of Lobsters, most species, including those which are very close to their respective supply constraints (e.g., Groundfish and Salmon) have exhibited only modest relative price changes.

For the purpose of illustration, let us drop the utility-maximization general equilibrium framework, and posit quantity consumed as a function of own price only. If we use the own price partials given in F_i^*[6] and solve for the changes in price consistent with Δx_i, we find the change in prices as follows:

$$(6.4)\quad \Delta p_i = \begin{pmatrix} .613758 \\ .838483 \\ .372705 \\ .266345 \\ 3.6064 \\ .27805 \end{pmatrix}$$

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[6]Of course, if we exclude the prices of other species and rerun our cross-sectional equations, different estimates of the implied own price partial derivatives are obtained. However, even when this is done, in no case is the difference greater than thirty percent on either side of the original estimates. Even if the difference is plus or minus fifty percent, the basic conclusion with respect to the rate of price increase with and without the inclusion of cross partials is not altered.

And, thus, the percentage change in prices is:

$$(6.5)\qquad (\Delta p_i)(1/p_i) = \begin{pmatrix} .599297 \\ .818727 \\ .363924 \\ .26007 \\ 3.55143 \\ .271499 \end{pmatrix}$$

The obvious conclusion is that rate of price increases is greater in a partial framework. It is precisely for this reason that the general equilibrium framework was used, i.e., to see if the movement of prices differs significantly. Even if different own price partials are used, the basic results are not altered: <u>leaving out the prices of other species overstates the common-property resource problem in terms of its impact upon prices.</u>[7]

The third and final part of the second section concerns the allocative significance of our framework. The reallocation of capital and labor depends upon the difference between the market solution and the constant utility locus solution along the indifference space. The market clearing quantity adjustment for the unconstrained species, Scallops and Oysters/Clams, is given by,

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[7] This specifically refers to the common-property resource problem in the inelastic portion of the supply function.

$$(6.6) \quad \Delta x_{n-i} = F^{*}_{n-i}\,\Delta p_i$$

$$\begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array}$$

$$\begin{pmatrix} 1.82513 & 1.45635 & .0630904 & 2.55035 & 2.55611 & 1.51052 \\ 5.24721 & 2.39561 & 3.4633 & 1.93442 & 1.3763 & 1.10988 \end{pmatrix}$$

$$\begin{array}{c} 7 \\ 8 \end{array} \begin{pmatrix} .0383676 \\ .0696286 \end{pmatrix} \quad \begin{pmatrix} .0130343 \\ .140441 \\ -.0542641 \\ -.102811 \\ .00796539 \\ .0366187 \end{pmatrix}$$

where 7 and 8 denote Scallops and Oysters/Clams respectively, and all other symbols have been previously defined. There are no price changes for these two species because of the assumption of perfect elasticity of supply.

We may derive another set of price changes by taking the 6x6 submatrix of substitution effects, F_i^{**}, and multiplying the inverse of F_i^{**} by Δx_i, so that:

$$(6.7) \quad (\Delta p_i)' = (F_i^{**})^{-1}\,\Delta x_i = \begin{pmatrix} .0130315 \\ .140426 \\ -.0542543 \\ -.102796 \\ .00796803 \\ .0366266 \end{pmatrix}$$

From (6.7) we can solve for the quantity adjustments necessary to stay along the community indifference curve by multiplying the 2x6 submatrix depicting the substitution effects between the unconstrained and constrained species, F^{**}_{n-i}, by (6.7). Thus,

$$(6.8)\quad \Delta x'_{n-i} = F^{**}_{n-i}\ \Delta p'_i =$$

$$\begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \\ \end{array}$$

$$\begin{pmatrix} 1.82519 & 1.45636 & .0631106 & 2.55043 & 2.55616 & 1.51056 \\ 5.24731 & 2.39562 & 3.46332 & 1.93449 & 1.37634 & 1.10992 \end{pmatrix}$$

$$\begin{array}{c} 7 \\ 8 \end{array} \begin{pmatrix} .0383902 \\ .0696473 \end{pmatrix} \qquad \begin{pmatrix} .0130315 \\ .140426 \\ -.0542543 \\ -.102796 \\ .00796803 \end{pmatrix}$$

The difference between $\Delta x'_{n-i}$ and Δx_{n-i}, is equal to:

$$(6.9)\quad (\Delta x'_{n-i} - \Delta x_{n-i}) = \begin{matrix} 2.25925 \times 10^{-5} \\ 1.87671 \times 10^{-5} \end{matrix}$$

Since (6.9) is in per capita dollar terms, we may obtain the total difference by multiplying both elements by the expected population. Then, we have,

$$(6.9)' \begin{pmatrix} 6953.97 \\ 5776.51 \end{pmatrix}$$

The sum of the two elements is equal to \$12,730.48. This gives us the loss, in aggregate dollars, of not following a policy of taking the economic resources necessary to produce ($\Delta x'_{n-i} - \Delta x_{n-i}$) out of the constrained subsectors. However, it is readily apparent that this loss is negligible, and the resource allocation involved so small that little policy is implied. This can be easily demonstrated in the following way. As a crude measure of the magnitude of the resource allocation involved,[8] we may obtain the quantity of capital and labor needed by multiplying each of these dollar amounts by their respective species conversion factors. Then, for given K/O and L/O ratios for Scallops and Oysters/Clams we can solve for the quantity of capital and labor needed to produce 5776.51 dollars of Oysters/Clams and 6953.97 dollars of Scallops. The necessary level of capital and labor, as well as the related information just discussed, are summarized in Table 6.2. The latter shows that to produce 4,799.6 pounds of Scallops and 317,650.3 pounds of Oysters/Clams would require only .429 units of labor and .022 units of capital for Scallops and 1.552 units of labor and .768 units of capital for Oysters/Clams. Thus, the capital and labor movement implied is only marginal at best.

This, of course, represents a point of view which minimizes the loss to society of the resource constraint and

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[8] This assumes that the increment can be produced domestically and thus abstracts from international trade considerations with respect to the unconstrained species.

Table 6.2

Relevant Data Regarding Allocation of Capital and Labor[1]

1. Scallops

a. Output per Vessel = 216,446.32 pounds
b. Output per Unit of Labor = 11,177.49 pounds
c. Weight/dollars of consumption = .081
d. Conversion Factor (Edible Weight to Live Weight) = 8.521
e. Total Dollars (eq. (6.13) x expected population) = 6953.97

Number of Vessels Allocated to Scallops = ((Weight/dollar consumption) x (Total Dollars) x (Conversion Factor))/Output per Vessel) = .0221

Number of Units of Labor Allocated to Scallops = ((Weight/dollar of consumption) x (Total Dollars) x (Conversion Factor))/Output per Unit of Labor) = .429402

2. Oysters/Clams

a. Output per Vessel = 413,704 pounds
b. Output per Unit of Labor = 204,689 pounds
c. Weight/dollar of consumption = 6.11
d. Conversion Factor (Edible Weight to Live Weight) = 9.0
e. Total Dollars (eq. (6.13) x expected population) = 5776.51

Number of Vessels Allocated to Oysters/Clams = ((Weight/dollar of consumption) x (Total Dollars) x (Conversion Factor))/Output per Vessel = .768

Number of Units of Labor Allocated to Oysters/Clams = ((Weight/dollar of consumption) x (Total Dollars) x (Conversion Factor))/Output per Unit of Labor = 1.55187

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[1] The basic source of information with respect to output per vessel, output per fisherman, was derived from Basic Economic Indicators, National Marine Fisheries Service, Economic Research Division.

assesses the market adjustment as practically 'optimal.' This may very well understate the intensity of the problem. Nonetheless, it is at least one indication that the extent of the projected misallocation may be limited.

3. A Note on Policy Implementation

Our empirical analysis has shown that within the conceptual framework developed in this study there is little difference between the market solution and the solution that would leave society as well off at the originally projected, but unattainable combination. Real price adjustments were found to be relatively modest. We have not examined adjustments across other food commodities, or other commodities in general. These adjustments have been assumed to take place but we have not examined them here. On the other hand, our conclusions must be qualified by the fact that the substitution effects were only linearized estimates, and hence, reflect only approximations of the true substitution effects.

It is also important to note that we have not concluded that there will be no redundancies. What is being said is that the magnitude of excessive entry of inputs will tend to be considerably dampened by the combination of the own and cross partials on the demand side and, at the very least, the imposition of a quota at maximum sustainable yield on the supply side. To the extent that a quota is presumed in effect, the market mechanism is modified. However, any modification of the market mechanism beyond the quota may have very small benefits. In other words, what we have found is that the 'modified' free market mechanism may perform rather well in terms of adjusting consumption, and by implication economic resources, away from supply constrained commodities to other commodities (i.e., other species of seafood and other food in general) where there are no inherent long-run supply constraints. That is not to say that in particular regions, for individual species, more sophisticated and more comprehensive management schemes are not needed.[9] Nor does it imply that the market solution will result in adequate management of all renewable natural resources. Certainly the possibility of over-exploitation and even extinction is an important area of study particularly when policy initiatives are not forthcoming. Rather, it is our contention that from a general equilibrium point of view -- and that has to be the framework in discussing the overall management objectives for all species -- the market, with some slight adjustments, may not perform so suboptimally that drastically revised policies are needed.

4. Conclusions: A Critique

In order to gain perspective and insight into the importance of this study, we will conclude with a brief discussion analyzing some of the shortcomings of the approach

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[9] For example, see "Technological Externalities and Common Property Resources: An Empirical Study of the U.S. Northern Lobster Fishery," by Frederick W. Bell; Journal of Political Economy (forthcoming).

and technique that were employed. There are, to be sure, a number of assumptions which, at best, might be considered highly restrictive. In addition, there are some critical questions that may be posed with respect to the statistical methods that were used in some parts of this research.

In the context of the general demand analysis, there are several points that can be raised. First, why was such an aggregative approach undertaken, i.e., why not restrict the analysis to the fishing sector? Secondly, the separate influence of time upon different species was not examined. That is, it was assumed that time, as a proxy for changes in consumers' taste, equally affected all subsectors in the fishing industry. However, there is no *a priori* reason why this should be the case. Thirdly, it might be argued that the method used to distribute the cross-sectional estimates of the income parameters for consistency with the 'control total' established in the time series analysis was rather arbitrary and not based upon any probabilistic or statistical conditions. Fourth, the assumption of a constant weight per dollar for each species in association with the mean price index for all seafood, while necessary in order to relate projected consumer *expenditure* with anticipated supply constraints (*in weight*), can be termed as an unusually heroic assumption. Finally, estimates of "substitution effects" that are contained in this study are parametric. There is no mention or any explanation of how these substitution effects change when the level of consumption changes.

There are also some unanswered questions on the supply side. For example, there is no test of the assumption that the market will clear at maximum sustainable yield. Furthermore, the analysis is fairly sensitive to the estimates of MSY, i.e., policy implications with respect to the reallocation of capital and labor depend upon the accuracy of the supply constraint estimates. Third, and last, these supply constraints are only valid to the extent that the imposition of a quota is guaranteed.

Some of these points may be handled in rather short order. The aggregative approach was undertaken in order to insure that the forecast was consistent with all other commodities. This acted as a constraint on the upper bound of the forecast, which is particularly important for resource related commodities, and which is lacking in other types of forecasting, such as single equation techniques. A second and related reason for the aggregative approach in this context is the degree to which the identification problem is minimized relative to other techniques. In other words, any sort of analysis which is confined to the fishing sector alone (e.g., a restricted least squares routine for n species) would have to contain the assumption that prices are exogenous. However, because of the common property nature of the resource, prices are not exogenous, and supply functions are not perfectly elastic at some given level of prices. Nonetheless, the importance of this factor is negligible in the aggregative approach because

(a) perfect elasticity of supply is a reasonable assumption for all commodities excluding seafood, and (b) because the latter constitutes such a small proportion of total consumer spending. At the same time, the implicit test of the additivity condition in the utility function for seafood (Appendix A) demonstrates that it is not at all an unreasonable assumption. The second point raised -- that with respect to the time variable -- is not relevant in this context. In other studies, where this same technique was applied, the purpose of the inclusion of the time variable was to make results, in terms of economic parameters, comparable to cross-sectional estimates.[10] Given the minor difference between the sum of the species coefficients and the time series seafood parameter, the purpose of including time has been fulfilled and is consistent with other studies. In addition, because of this minor difference the method of distributing individual species coefficients becomes a moot issue. The issue of a constant weight per dollar is not unrealistic when one considers that, conceptually, holding

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[10]" . . . But we do hasten to point out that any attempt to suppress trends makes interpretation of the data, in terms of economic constructs, almost impossible. Clothing is a case in point. Suppressing trends in equations attempting to explain Clothing consumption in the post-war period leads to results which simply cannot be squared at all with cross-sectional data. This remark applies to several countries . . . and to single equation techniques . . . as well as to simultaneously fitted systems . . ." A.A. Powell, Tran Van Hoa, and R.H. Wilson, "A Multi-Sectoral Analysis of Consumer Demand in the Post-War Period", in The Southern Economic Journal, Vol. XXXV, No. 2, p. 120.

price constant should be equivalent to holding weight per dollar consumed constant, and that a fairly high correlation was found between changes in the price index and changes in dollars/weight consumed. The last point with respect to the demand analysis -- the linearization of substitution effects -- is a valid and relevant criticism. However, linear approximations to non-linear systems are certainly nothing new in the economic literature. In fact, linear approximations are often used in a partial equilibrium framework; here, we have extended this to a more general equilibrium frame of reference. In fact, linear estimates of price derivatives (with implied linear substitution effects) have been used in an intermediate to long-run forecasting context.[11]

The points raised with respect to the supply variables are not major. That the market _ultimately_ would clear at maximum sustainable yield for the constrained subsectors is quite certain. The only question is "when?". We have forecasted far enough into the future so that clearance at MSY is probably justified. Secondly, there appears to be a consensus among biologists (at least with respect to the species in the United States) regarding potential yield. At any rate, policy implications will always be sensitive to forecasts of 'exogenous' variables, i.e., aggregate consumer spending, disposable income, population, etc. Thirdly, we have estab-

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[11] See Leif Johansen, _A Multi-Sectoral Study of Economic Growth_.

lished that there is some historical precedent for the imposition of a quota. Of course, it could be argued that the quota is not necessarily imposed at MSY, but sometime afterward (overfishing in the biological sense). In that case, though, the reallocation of capital and labor from the constrained subsectors to the unconstrained subsectors would increase output in both categories.

In the end, the most important contribution of this study may be in the identification of important demand parameters, and the significance the use of those parameters would have in a forecasting context or in a framework in which relative price changes are measured across species. We have shown that the inclusion of cross partial derivatives can change some of the conclusions reached in the traditional analysis, i.e., the rate of change of price is considerably dampened when cross price partials are put into the analysis. Furthermore, although significant policy implications were not reflected in this study, this approach will hopefully lay the foundation for the type of analysis within which policy is evaluated in a general equilibrium framework.

APPENDIX A

TEST OF ADDITIVITY ASSUMPTION

An implicit test of the additivity assumption with respect to the seafood category involves the estimation of what Frisch refers to as the flexibility of the marginal utility of money,

$$\text{(A.1)} \qquad \omega = \frac{\partial \lambda}{\partial m} \frac{m}{\lambda} ,$$

where λ is equal to the marginal utility of money, and m is equal to (as before) aggregate per capita expenditures. The test would consist of a comparison of w obtained in other studies in which the additivity assumption is employed, but in which the seafood category is not separated. If the results are comparable, it would indicate that the additivity assumption for fish is valid, or at the very least that the parameter, $\hat{\gamma}$, is not sensitive to the inclusion of very disaggregated commodities as separate entities under the general additivity assumption. (A.1) may be computed at the mean per capita expenditure level, so that:

$$\text{(A.2)} \qquad \hat{\omega} = -\bar{m}/\hat{\gamma}$$

has been found to be 1,030.3, while m is equal to 1,826.29 dollars. Accordingly, w is equal to -1.77. According to Powell, the general range of w for various countries has been

-1.5 to -2.5.[1] For the United States, Powell estimated a value of -1.507.[2] Thus, our estimate is within a general range and at the same time is very close to the United States value. It may therefore be concluded that within an empirical context the additivity assumption for seafood is eminently reasonable. Sensitivity of the flexibility of the marginal utility of money was used by Frisch as a criterion for testing the same type of assumption with respect to a similarly disaggregated food commodity and there, too, positive results were forthcoming.[3]

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1 Powell, "A Complete System of Consumer Demand Equations for the Australian Economy Fitted by a Model of Additive Preferences," p. 674.

2 Powell, Tran Van Hoa, and Wilson, "A Multi-Sectoral Analysis of Consumer Demand in the Post-War Period," p. 116. The results for the United States are not exactly comparable because the authors include quadratic Engel curves, while most of the other studies cited use linear Engel curves.

3 Frisch (13).

APPENDIX B

CONVERGENCE OF $\lambda(\hat{\gamma})$

The path to convergence is depicted in figure B.1. After the third iteration, where λ reached a value of 1,030.34, it fluctuated between 1,030.0 and 1,031.0 with no discernible pattern. Table B.1 shows the convergence path of λ with the estimated parameters at each iteration.

FIGURE B.1
CONVERGENCE PATH OF λ

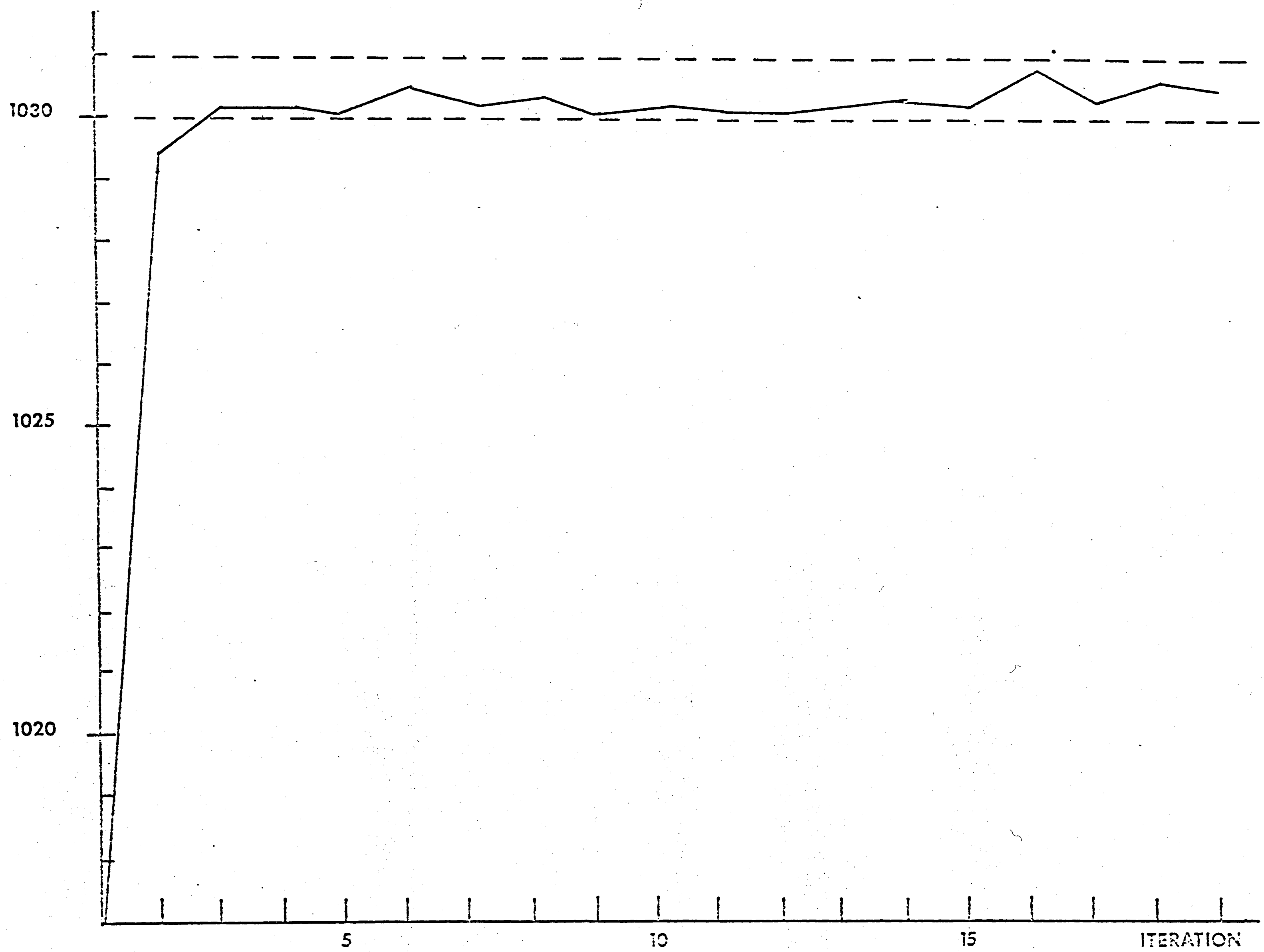

Table B.1

CHANGE IN ESTIMATED PARAMETERS FROM ITERATION TO ITERATION

	B					C				
Iteration #	B_1	B_2	B_3	B_4	B_5	C_1	C_2	C_3	C_4	C_5
1										
2	-.00201570	.0819943	.288423	.275435	.35213200	-.0665606	-.289285	-3.1855	-4.04649	7.5878356
3	.00202864	.0820221	.288578	.275064	.35230726	-.066901	-.286846	-3.1786	-4.04759	7.579937
4	.00203114	.0820193	.28856	.275111	.35227856	-.0669884	-.287148	-3.17955	-4.04715	7.5808364
5	.00203160	.0820157	.288557	.275116	.35227970	-.0670019	-.286924	-3.17908	-4.04707	7.5800759
6	.00203190	.0820238	.288567	.275092	.35228530	-.0670114	-.287293	-3.17976	-4.04731	7.5813744
7	.00203184	.0820202	.28856	.275107	.35228096	-.0670099	-.287154	-3.17941	-4.04715	7.5807239
8	.00203188	.0820217	.288563	.2751	.35228342	-.0670109	-.287204	-3.17956	-4.04722	7.5809949
9	.00203186	.0820205	.288561	.275104	.35228264	-.0670103	-.287159	-3.17945	-4.04717	7.5807893
10	.00203182	.0820192	.28856	.275107	.35228198	-.0670092	-.287092	-3.17934	-4.04715	7.5805912
11	.00203180	.0820183	.28856	.275109	.35228090	-.0670085	-.287047	-3.1793	-4.04715	7.5805055
12	.00203180	.0820181	.28856	.275109	.35228092	-.0670083	-.287036	-3.17929	-4.04715	7.5804843
13	.00203181	.0820188	.288561	.275107	.35228139	-.0670088	-.28707	-3.17935	-4.04716	7.5805888
14	.00203183	.0820193	.288561	.275105	.35228287	-.0670094	-.287098	-3.1794	-4.04717	7.5806774
15	.00203182	.082019	.288561	.275107	.35228118	-.0670091	-.287081	-3.17936	-4.04713	7.5805801
16	.00203203	.082028	.288571	.275082	.35228697	-.0670157	-.2875	-3.18009	-4.04739	7.5819957
17	.00203186	.0820209	.28856	.275108	.35227924	-.0670107	-.287193	-3.17944	-4.04711	7.5807537
18	.00203198	.0820259	.288567	.275089	.35228612	-.0670139	-.2874	-3.17985	-4.04731	7.581539

1. Seafood
2. All other food
3. Other non-durables
4. Durables
5. Services

APPENDIX C

THE DEFINITION OF MAXIMUM SUSTAINABLE YIELD: SOME REGIONAL RAMIFICATIONS

Our purpose here is to elaborate upon the concept of MSY and to examine one of the major assumptions of this study in the light of regional differences in resource potential. The assumption to which we allude is that once MSY is reached, output is maintained at that level because of regulations designed to keep the effective level of output "frozen." As we shall show, once regional disparities are introduced, these two phenomena are not independent, i.e., regulations on a regional basis have to be imposed so as to assure the attainment of maximum yield on a world basis.

In order to pinpoint the impact of regional differences, we must first derive an expression for the long-run supply curve. This may be done in the context of a technique developed by F.V. Waugh. Assume that a relative yield curve can be specified,

$$\text{(C.1)} \qquad \frac{Y_t}{Y_1} = a\left(\frac{e_t}{e_1}\right) - b\left(\frac{e_t}{e_1}\right)^2,$$

where y_t and e_t are the yield and effort respectively in any given year, and y_1 and e_1 are the yield and effort for some given base period. When $e_1 = e_t$, $y_1 = y_t$ and the following relationship holds, (C.2) $a - b = 1$

Thus, we may express b in terms of a. Differentiating (C.1) and setting it equal to zero, we may derive an expression for relative effort at the maximum of the function in terms of a. Substituting back into (C.1), gives,

(C.3) $$\frac{y^*}{y_1} = \frac{a^2}{(4a-4)}$$

where y^* is equal to MSY. We may then solve for "a"

(C.4) $$a = 2y^*/y_1 \ (1 \pm \sqrt{1-y_1/y^*})$$

Since $(1- \sqrt{1-y_1/y^*})$ is the only expression which fits the yield effort function, the other possible value of "a" is ignored. Thus, if maximum sustainable yield and some base period level of landings are both known, then "a" and "b" can be obtained. Furthermore, if we assume that the ratio $\frac{e_t}{e_1}$ is equal to the ratio of total costs, $\frac{TC_t}{TC_1}$, and that price is equal to average cost in the base period, we can substitute p_1y_1 for TC_1 and p_ty_t for TC_t and obtain the following:

(C.5) $$y_t = \frac{ap_1y_1}{bp_t} - \frac{p_1^2y_1}{bp_t^2}$$

Thus, with p_1 y_1 "a" and "b" as constants, we have quantity as a function of price only.

Differentiating (C.5) with respect to price, and setting the resultant expression equal to zero, we may obtain the price, p^*, at which maximum sustainable yield is attained:

$$(C.6) \quad P^* = 2p_1/a$$

Substituting (C.6) into (C.5) gives,

$$(C.7) \quad Y^* = \frac{a^2 y_1}{4b}$$

Let us now assume that there are n regions. The sum of the regional maximum yields is then given by:

$$(C.8) \quad \sum_{i=1}^{n} y_i^* = \sum_{i=1}^{n} \left(\frac{a_i^2}{4b_i} y_{1_i} \right),$$

where y_{1_i}, a_i and b_i are, respectively, the yield function parameters and the base period level of landings in the i^{th} region. (C.8) represents a global upper bound, a "maximum maximorium." On the other hand, let us define the world supply function as the sum of the regional supply schedules,

$$(C.9) \quad \sum_{i=1}^{n} y_{t_i} = \sum_{i=1}^{n} \left(\frac{ap_1 y_{1_i}}{bp_t} - \frac{p_1^2 y_{1_i}}{bp_t^2} \right)$$

Differentiating (C.9) with respect to price and then setting it equal to zero, we can solve for the price at which the world supply function reaches a maximum,

$$(C.10) \quad P_s^* = \frac{2P_1 \sum_{i=1}^{n} y_{1_i}/b_i}{\left(\sum_{i=1}^{n} y_{1_i} a_i/b_i \right)}$$

When (C.10) is substituted into (C.5), the maximum point of the world supply function can be found,

(C.11)

$$\left(\sum_{i=1}^{n} y_{t_i}\right)^* = \frac{1}{4}\,\frac{\left[\sum_{i=1}^{n}\left(\frac{a_i}{b_i}\,y_{1_i}\right)\right]^2}{\sum_{i=1}^{n}\left(\frac{y_{1_i}}{b_i}\right)}$$

In general, (C.11) will be less than (C.8)[1], but will approach (C.8) as differences in regional yield coefficients become smaller. When the regional coefficients are the same, the following holds:

(C.12)

$$\left(\sum_{i=1}^{n} y_{t_i}\right)^* = \frac{1}{4}\,\frac{\left[\sum_{i=1}^{n}\frac{a_i}{b_i}y_{1_i}\right]^2}{\sum_{i=1}^{n}\left(\frac{y_{1_i}}{b_i}\right)} = \frac{\frac{1}{4}\,\frac{a^2}{b^2}\left[\sum_{i=1}^{n} y_{1_i}\right]^2}{\frac{1}{b}\sum_{i=1}^{n} y_{1_i}} = \frac{1}{4}\,\frac{a^2}{b}\sum_{i=1}^{n} y_{1_i}$$

However, it is also true that

(C.13)

$$\frac{1}{4}\,\frac{a^2}{b}\sum_{i=1}^{n} y_{1_i} \equiv \sum_{i=1}^{n}\left(\frac{a_i^2}{4b_i}y_{1_i}\right) \equiv \sum_{i=1}^{n} y_i^*$$

Thus, world maximum sustainable yield can be attained in the market only if the regional yield parameters are the same.

Thus, within the context of the technique discussed, any one of three conditions would be sufficient to permit the maximum resource potential from the world's oceans to be

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[1]A general statement about the relationship between (C.10) and (C.6) cannot be made. In other words, we cannot say a priori whether the price at which MSY is reached will be higher or lower than the price consistent with the maximum of the world supply function.

harvested: first, if world yield and world landings are equally distributed between regions; secondly, if the ratio of landings to maximum sustainable yield is the same in all regions;[2] and, finally, if each regions' harvest rate is "frozen" -- via regulations maintaining the level of the permissible harvest rate -- at regional MSY. The ultimate effect of these regional variations is basically an empirical question. However, it is possible that for some species the impact of the spatial dimension could be significant, i.e., a considerable difference could arise between MSY and maximum supply.

What all of this means is that we have assumed that MSY is reached and then regulations imposed ad hoc to maintain yield at that level. We have thus assumed away regional problems, or, more to the point, presumed that at best one of three conditions cited above is met.

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[2] It should be pointed out that the slope of the absolute supply curve, i.e., $y_t = f(p_t)$, does depend upon the absolute level of base period landings, y_1; however, the elasticity of supply does not. Thus, the attainment of MSY merely depends upon the assumption that all regional supply curves have the same elasticity. The formula for the price elasticity of supply is given by:

$$E_s = \frac{p_t}{y_t}\frac{dy_t}{dp_t} = \left[\frac{p_1}{ap_t - p_1}\right] - 1,$$

and thus is independent of base period landings.

The limite of E_s as $p_t \to p^* = 0$, i.e., when $p_t = p^*$, the elasticity of supply is equal to zero.

APPENDIX D

QUANTITY ADJUSTMENTS

A significant feature of the quantity adjustments derived in chapter six is that they do not critically depend upon the transformation made in the total system of cross partials (i.e., setting $\frac{\partial \lambda}{\partial y} = -1$). This can be demonstrated rather easily. Given the quantity adjustments for the constrained subsectors Δx_i (i=1, ...6) -- determined jointly by MSY and forecasted consumption --, the change in either one of the unconstrained species along the "indifference curve" is:

(D.1)

$$\frac{\Delta x_7}{\Delta x_i} = \frac{\sum_{j=1}^{6} k_{7j} \Delta p_j}{\sum_{j=1}^{b} k_{ij} \Delta p_j} \equiv \frac{\lambda \sum_{j=1}^{6} F_{7j} \Delta p_j}{\lambda \sum_{j=1}^{b} F_{ij} \Delta p_j} \equiv \frac{\sum_{j=1}^{6} F_{7j} \Delta p_j}{\sum_{j=1}^{b} F_{ij} \Delta p_j}$$

(D.2)

$$\frac{\Delta x_8}{\Delta x_i} = \frac{\sum_{j=1}^{6} k_{8j} \Delta p_j}{\sum_{j=1}^{b} k_{ij} \Delta p_j} \equiv \frac{\lambda \sum_{j=1}^{6} F_{8j} \Delta p_j}{\lambda \sum_{j=1}^{b} F_{ij} \Delta p_j} \equiv \frac{\sum_{j=1}^{6} F_{8j} \Delta p_j}{\sum_{j=1}^{b} F_{ij} \Delta p_j}$$

where K_{ij} is the i, jth substitution effect, Δx_7 and Δx_8 are quantity adjustments for Scallops and Oysters/Clams respectively, and F_{ij} is the i, jth element of substitution matrix divided by λ, the marginal utility of income. As long as the Δx_i are reliable, the quantity adjustments for the unconstrained subsectors will also be reliable.

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"On Models of Commercial Fishing: A Defense of the Traditional Literature," with Frederick W. Bell and Ernest W. Carlson, Journal of Political Economy, forthcoming.

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APPROVAL SHEET

Title of Thesis: A General Equilibrium Demand Model for Living Marine Resources: An Application of General Equilibrium and Common Property Resource Theory to the U.S. Seafood Sector

Name of Candidate: Richard F. Fullenbaum
Doctor of Philosophy, 1971

Thesis and Abstract Approved: Frederick W. Bell

Frederick W. Bell
Professor
Economics Department

Date Approved: August 11, 1971

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Table 3.1

Commodity Groupings*

1. All Seafood

2. All Other Food

   All Food Purchases Minus Seafood, Minus Alcoholic Beverages and Tobacco Products

3. All Other Non-Durable Commodities

   a. Alcoholic Beverages

   b. Tobacco products

   c. Clothing and shoes

   d. Gasoline and oil

   e. Other nondurable goods (excluding tobacco products)

4. Durable goods

   a. Autos and parts

   b. Furniture and household equipment

   c. Other durable goods

5. Services

   a. Housing

   b. Household operation services

   c. Transportation services

   d. Other services

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* Source for categories 3-5: Survey of Current Business, National Income Issue, July, 1969, p. 49. Seafood expenditures estimates were obtained from the Bureau of Commercial Fisheries; category 2 was calculated by differencing the seafood from the food group. The latter is also published in the Survey of Current Business.

Table 3.2

Per Capita Expenditures by Commodity*

	t	Seafood	All Other Food	All Other Non-durable Commodities	Durable Commodities	Services	Per capita expenditures Total
1952	-7	12.2816	337.491	378.84	187.566	469.298	1385.48
1953	-6	11.61895	337.251	385.874	209.156	502.837	1446.75
1954	-5	11.55276	337.661	381.421	202.837	527.415	1460.89
1955	-4	10.79887	341.012	395.204	240.136	553.908	1541.06
1956	-3	11.18584	348.369	409.458	231.545	585.961	1586.52
1957	-2	12.2282	360.99	418.834	238.307	613.645	1644.
1958	-1	12.5854	370.024	422.173	217.521	643.334	1665.64
1959	0	12.3955	373.96	441.392	250.126	679.019	1756.89
1960	1	12.1173	377.416	451.031	251.644	714.765	1806.97
1961	2	12.5245	381.194	457.945	241.346	737.852	1830.86
1962	3	12.9021	387.232	474.345	266.502	769.057	1910.04
1963	4	12.713	392.846	488.291	285.851	807.928	1987.63
1964	5	12.6887	409.986	512.901	309.538	853.317	2098.43
1965	6	13.3056	429.529	542.946	342.12	905.358	2233.26
1966	7	14.28	455.318	586.613	361.121	962.858	2380.19
1967	8	14.6587	458.254	614.018	368.99	1032.04	2487.96

Source: Survey of Current Business, and Bureau of Commercial Fisheries.

Table 3.3

Price Indices For Five Commodity Groups*

Year	Seafood	All Other Food	All Other Non-durable Commodities	Durable Commodities	Services
1952	.974	.953	.929	.954	.836
1953	.938	.938	.938	.943	.877
1954	.943	.936	.945	.929	.900
1955	.924	.922	.948	.919	.920
1956	.923	.929	.967	.949	.946
1957	.935	.96	.993	.984	.973
1958	1.000	1.000	1.000	1.000	1.000
1959	1.018	.984	1.012	1.014	1.030
1950	1.02	.995	1.025	1.009	1.058
1961	1.042	1.007	1.031	1.006	1.076
1962	1.085	1.017	1.038	1.008	1.090
1963	1.083	1.031	1.048	1.004	1.109
1964	1.058	1.044	1.053	1.004	1.131
1965	1.089	1.068	1.068	.996	1.151
1966	1.16	1.121	1.09	.987	1.183
1967	1.194	1.13	1.124	1.003	1.221

*Source: For all categories except "Seafood", OBE Implicit Price Deflators were used for the relevant price indicators. That is, for "Durable Commodities", "Services", and "All Other Food", the deflators were taken directly from the Survey of Current Business (July 1969 and 1970 issues, and National Income Account Supplement). For the classification, "All Other Non-Durable Commodities", a weighted average of the indicators of components listed in Table 3.1 (with weights based upon expenditures in the base year, 1958) was used. Finally, the "Seafood" price indicator is the BLS estimate of the CPI for seafood purchases. Although not all seafood commodities are included in deriving this index, in terms of value it is a fairly good indicator of the direction of change of total seafood cost. In other words, the seafood commodities that are included in the index comprise a fairly large proportion of the total value of seafood purchases, and thus, over a long period of time the BLS index would represent a fairly accurate price index.

Table 3.4

Major Results Of Time Series Analysis

Commodity	b value	c value	t ratio for b	t ratio for c	R^2y[1]	R^2v[1]	Durbin-Watson Statistic*
1. Seafood	.002032	-.067010	1.5933	-1.2242	.192	.889	1.402 *
2. All Other Food	.082021	-.287165	7.6307	- .6224	.968	.995	1.118 **
3. All Other Non-durable Commodities	.288561	-3.17945	17.2800	-4.4360	.991	.996	1.666 *
4. Durable Commodities	.275104	-4.04716	8.7782	-3.0088	.957	.978	1.791 *
5. Services	.352282	7.58079	13.5777	6.8074	.996	.998	1.358 *
	Total 1	Total 0					

[1] Following Powell, we define R^2y and R^2v respectively as:

$$(1.1)' \quad R^2y = 1 - \sum_t e_{it}^2 \Big/ \sum_t (y_{it})^2$$

$$(1.2)' \quad R^2v = 1 - \sum_t e_{it}^2 \Big/ \sum_t (V_{it} - \bar{V})^2$$

*Insignificant at the .05 level, i.e. accept null hypothesis of no autocorrelation.

**Significant at the .05 level, i.e. reject null hypothesis of no positive autocorrelation.

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.1 Shrimp*

Variables	Regression	T Ratio
1. Constant	- .15422808	
2. Family Size	- .38971170	- 1.996
3. Jewish	.39735955	.2346
4. Catholic	.20096034	.3430
5. Negro	.94626299	.8803
6. Income	$.57201015 \times 10^{-3}$	5.337
7. Price of Shrimp	.36276636	.7522
8. Price of Oysters/Clams	.43292527	.6944
9. Price of Tuna	1.2927260	1.133
10. Price of Lobsters	.49173035	.9758
11. Price of Crabs	- .30729344	- .5468
12. Price of Groundfish	- .34823279	- .7025
13. Price of Scallops	1.8690439	1.612
14. Price of Salmon	- 1.9728542	- 2.047

$R^2 = .2105$
$F(13,131) = 5.229$
269 observations
*Household Level

Table 4.2 Crabs*

Variables	Regression	T Ratio
1. Constant	- 2.5973228	
2. Family Size	- .51076755	- 2.095
3. Jewish	- .29550586	- .1700
4. Catholic	.16485509	.2125
5. Negro	1.0459726	.7980
6. Income	$.15292862 \times 10^{-3}$	1.453
7. Price of Shrimp	- 1.3957403	- 1.196
8. Price of Oysters/Clams	2.4533307	4.561
9. Price of Tuna	.2333424	.1770
10. Price of Lobsters	- .79732715	- 1.271
11. Price of Crabs	.37532200	.9727
12. Price of Groundfish	.90026434	1.349
13. Price of Scallops	1.4914521	1.880
14. Price of Salmon	1.8757360	1.273

$R^2 = .2896$
$F(13,131) = 4.108$
145 observations
*Household Level

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.3 Lobsters*

Variables	Regression	T Ratio
1. Constant	1.0561374	
2. Family Size	- 2.3567350	- 1.730
3. Jewish	12.494558	1.588
4. Catholic	2.6911149	.7357
5. Negro	- 1.0744252	- .1751
6. Income	$.99434587 \times 10^{-3}$	1.732
7. Price of Shrimp	- 10.333537	- 1.470
8. Price of Oysters/Clams	3.5462620	1.246
9. Price of Tuna	8.4653988	1.456
10. Price of Lobsters	- 1.4358317	- .4544
11. Price of Crabs	- 4.0015255	- 1.639
12. Price of Groundfish	7.2728524	1.757
13. Price of Scallops	3.3904472	.4109
14. Price of Salmon	- 2.3470448	- .3951
15. Region 1 (New England)	11.783367	2.670

$R^2 = .2655$
$F(14,88) = 2.272$
103 observations
*Household Level

Table 4.4 Tuna*

Variables	Regression	T Ratio
1. Constant	2.1551427	
2. Family Size	- .53630125	- 2.181
3. Jewish	4.7877022	3.234
4. Catholic	1.2869883	1.563
5. Negro	1.3242350	.7351
6. Income	$.52064527 \times 10^{-3}$	4.087
7. Price of Shrimp	.29495419	.2454
8. Price of Oysters/Clams	- 1.3211467	- 1.932
9. Price of Tuna	1.4256136	1.134
10. Price of Lobsters	- 2.2623598	- 2.732
11. Price of Crabs	- 1.2179128	- 1.511
12. Price of Groundfish	- 0.65698295	- .2570
13. Price of Scallops	2.6118043	1.489
14. Price of Salmon	1.3856402	1.039
15. Region 3 (E. North Central)	- 2.7532983	- 1.258

$R^2 = .1144$
$F(14,553) = 5.102$
568 observations
*Household Level

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.5 Salmon*

Variables	Regression	T Ratio
1. Constant	3.5728217	
2. Family Size	- 1.3031244	- 7.116
3. Jewish	1.6826125	1.501
4. Catholic	.84853194	1.339
5. Negro	1.6436091	1.486
6. Income	- $.35369545 \times 10^{-3}$	- 3.760
7. Price of Shrimp	- .94772349	- .9974
8. Price of Oysters/Clams	1.4097796	2.443
9. Price of Tuna	3.5008448	3.118
10. Price of Lobsters	- 1.5162591	- 2.446
11. Price of Crabs	- 2.5926624	- 3.485
12. Price of Groundfish	.083418719	.4802
13. Price of Scallops	2.6179570	1.806
14. Price of Salmon	1.9080569	2.214
15. Region 6 (E. South Central)	4.3450070	3.681

R^2 = .1648
F(14,649)= 9.147
664 observations
*Household Level

Table 4.6 Groundfish*

Variables	Regression	T Ratio
1. Constant	3.5728217	
2. Family Size	- .87508520	- 6.109
3. Jewish	4.4276207	4.715
4. Catholic	.89307483	1.810
5. Negro	.85757961	.8395
6. Income	$.4822618 \times 10^{-4}$	.5901
7. Price of Shrimp	$.20798203 \times 10^{-2}$	$.2904 \times 10^{-2}$
8. Price of Oysters/Clams	1.1366709	2.799
9. Price of Tuna	.33975922	.3528
10. Price of Lobsters	- .91863856	- 1.939
11. Price of Crabs	- .62263491	- 1.227
12. Price of Groundfish	.28388664	1.985
13. Price of Scallops	.53539537	.5194
14. Price of Salmon	1.2849187	1.583

R^2 = .1224
F(13,686)= 7.363
700 observations
*Household Level

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.7 Scallops*

Variables	Regression	T Ratio
1. Constant	$.75990320 \times 10^{-2}$	
2. Family Size	$-.10408690 \times 10^{-2}$	- .3577
3. Jewish	$-.55673546 \times 10^{-2}$	- .2961
4. Catholic	$.24893807 \times 10^{-2}$	.4471
5. Negro	- .010530830	- .7003
6. Income	$.22100429 \times 10^{-4}$	.8305
7. Price of Shrimp	- .24718550	- .8012
8. Price of Oysters/Clams	.14102436	1.587
9. Price of Tuna	.90205951	1.244
10. Price of Lobsters	.064512793	.4244
11. Price of Crabs	- .31757226	- .9826
12. Price of Groundfish	- .25461606	- .8327
13. Price of Scallops	- .31067389	- 1.538
14. Price of Salmon	.23483592	.9983
15. Region 1 (New England)	.57676508	2.663
16. Region 3 (E. North Central)	- .092433424	- .4404
17. Region 4 (W. North Central)	- .35238189	- 1.697
18. Region 5 (South Atlantic)	.14491541	.6309
19. Region 6 (E. South Central)	- .33413667	- 1.378
20. Region 7 (W. South Central)	- .20323267	- .7543
21. Region 8 (Mountain)	.42891991	1.869

$R^2=.5200$
$F(20,38)=$
2.058
59 observations
*Group Data

Table 4.8 Oysters/Clams*

Variables	Regression	T Ratio
1. Constant	- .69186598	
2. Family Size	$.16764543 \times 10^{-2}$	.3778
3. Jewish	- .011206073	- .4221
4. Catholic	$-.62880804 \times 10^{-2}$	- .7496
5. Negro	.012111786	.5860
6. Income	$.19404949 \times 10^{-4}$	.4970
7. Price of Shrimp	.22734418	.5050
8. Price of Oysters/Clams	.082459048	.6658
9. Price of Tuna	1.9810963	2.124
10. Price of Lobsters	- .10145901	- .6436
11. Price of Crabs	- .22149882	- .8938
12. Price of Groundfish	- .22328715	- .4813
13. Price of Scallops	- .14894086	- .5037
14. Price of Salmon	- .30010058	- .8315
15. Region 3 (E. North Central)	- .52994178	-1.916
16. Region 4 (W. North Central)	- .40008992	-1.517
17. Region 6 (E. South Central)	1.1130824	3.852

$R^2-.4436$
$F(16,54)=$
2.690
*Group Data

Table 4.11

MATRIX OF SUBSTITUTION EFFECTS

Price of Species j

Quantity of Species i	Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/ Clams
Shrimp	- 2.42817	-13.1687	-10.0872	1.26434	- 1.92511	- .338838	1.82519	5.24731
Crabs	-13.1687	- .138761	1.09809	-1.18895	- 2.53176	.879372	1.45636	2.39562
Lobsters	-10.0872	1.09809	- 2.28779	12.143	- 1.48086	7.10357	.0631106	3.46332
Tuna	1.26434	- 1.18895	12.143	-2.13379	1.12462	.331929	2.55043	1.93449
Salmon	- 1.92511	- 2.53176	- 1.48086	1.12462	- .273365	-15.4262	2.55616	1.37634
Ground-fish	- .338833	.879372	7.10357	.331929	-15.4262	- 1.75351	1.51056	1.10992
Scallops	1.82519	1.45636	.0631106	2.55043	2.55616	1.51056	- .617979	-11.8038
Oysters/ Clams	5.24731	2.39562	3.46332	1.93449	1.37634	1.10992	-11.8038	- .520134

Table 4.12

MATRIX OF PRICE DERIVATIVES

Quantity of Species i	Price of Species j: Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/ Clams
Shrimp	-2.4298	-13.169	-10.0877	1.26227	-1.92637	-.340028	1.82501	5.24696
Crabs	-13.1691	-.13884	1.09795	-1.1895	-2.5321	.879053	1.45631	2.39553
Lobsters	-10.0901	1.09757	-2.28869	12.1394	-1.48304	7.10149	.0627888	3.46271
Tuna	1.26285	-1.18922	12.1425	-2.13568	1.12347	.330842	2.55027	1.93417
Salmon	-1.9241	-2.53158	-1.48053	1.1259	-.272588	-15.4254	2.55627	1.37656
Ground-fish	-.338971	.879347	7.10353	.331754	-15.4263	-1.75361	1.51055	1.10989
Scallops	1.82513	1.45635	.0630904	2.55035	2.55611	1.51052	-.617987	-11.8038
Oysters/ Clams	5.24726	2.39561	3.4633	1.93442	1.3763	1.10988	-11.8038	-.520146

Table 4.13A

MATRIX OF PRICE ELASTICITIES *

Quantity of Species i	Price of Species j: Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/ Clams
Shrimp	-.852202	-4.61876	-3.53805	.442715	-.675635	-.119258	.640085	1.84026
Crabs	-25.4469	-.268283	2.12159	-2.2985	-4.89283	1.69861	2.81406	4.62893
Lobsters	-11.1114	1.20866	-2.52034	13.3681	-1.63315	7.82027	.069144	3.81319
Tuna	.349547	-.329166	3.36095	-.591139	.310967	9.15744×10^{-2}	.705894	.535363
Salmon	-.8797	-1.15744	-.6769	.514762	-.124627	-7.05251	1.16873	.629364
Ground-fish	-.162981	.422801	3.41546	.159511	-7.41715	-.843157	.726291	.533649
Scallops	5.66415	4.51967	.195796	7.91482	7.93269	4.68778	-1.91788	-36.6322
Oysters/ Clams	8.52996	3.89431	5.62995	3.1446	2.23732	1.80422	-19.1883	-.845551

* Footnotes are explained in Supplemental Table 4.13B.

Table 4.14

MATRIX OF ELASTICITIES OF SUBSTITUTION

j

Quantity of Species i	Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/ Clams
Shrimp	-545.534	-16300.2	-7115.63	224.175	-563.81	-104.359	3628.44	5464.14
Crabs	-16300.2	-946.29	4267.64	-1161.43	-4085.14	1492.2	15951.	13743.9
Lobsters	-7115.63	4267.64	-5067.09	6760.05	-1361.73	6869.46	393.925	11323.4
Tuna	224.175	-1161.43	6760.05	-298.577	259.935	80.6812	4001.35	1589.76
Salmon	-563.81	-4085.14	-1361.73	259.935	-104.365	-6193.55	6624.22	1868.3
Ground-fish	-104.359	1492.2	6869.46	80.6812	-6193.55	-740.385	4116.73	1584.46
Scallops	3628.44	15951.	393.925	4001.35	6624.22	4116.73	-10870.6	-108762.
Oysters/ Clams	5464.14	13743.9	11323.4	1589.76	1868.3	1584.46	-108762.	-2510.4

Table 4.15

MATRIX OF LINEAR PRICE COEFFICIENTS (RESTRICTED)

Price of Species j

Expenditures of Species i	Shrimp	Crabs	Lobsters	Tuna	Salmon	Ground-fish	Scallops	Oysters/ Clams
Shrimp	.362769	-13.4868	-10.3311	1.29273	-1.97285	-.348233	1.86905	5.37357
Crabs	-13.4869	.375322	1.12444	-1.2182	-2.5932	.900265	1.49145	2.45333
Lobsters	-10.3336	1.12405	-1.43583	12.4323	-1.51883	7.27285	6.43039×10^{-2}	3.54627
Tuna	1.29332	-1.21792	12.4355	1.42561	1.15058	.338825	2.61181	1.98084
Salmon	-1.97053	-2.59267	-1.51626	1.15307	1.90806	-15.7976	2.61795	1.40978
Groundfish	-.34715	.900566	7.27494	.339759	-15.7985	.283889	1.547	1.13667
Scallops	1.86917	1.49149	6.46128×10^{-2}	2.61189	2.61779	1.54697	-.310674	-12.0886
Oysters/ Clams	5.37388	2.45342	3.54687	1.9811	1.40951	1.13666	-12.0886	8.24592×10^{-2}

Table 5.3

MATRIX OF FORECASTED PER CAPITA SEAFOOD EXPENDITURE

Year	Species							
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Groundfish	Scallops	Oysters & Clams
1975	3.55799	.607129	1.77204	2.50763	2.34044	1.47448	.298867	.806224
1980	3.79602	.640361	2.21645	2.72056	2.1261	1.45655	.268167	.774207
1985	4.02057	.669992	2.63744	2.92123	1.92009	1.43748	.236946	.741733
1990	4.26183	.704088	3.08747	3.13709	1.70375	1.41982	.206371	.709825
2000	4.99587	.839524	4.42475	3.79776	1.11555	1.4057	.154938	.654542

Table 5.4

DEFLATED MATRIX OF FORECASTED PER CAPITA SEAFOOD EXPENDITURES

Year	Species							
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Groundfish	Scallops	Oysters & Clams
1975	3.47402	.5928	1.73022	2.44845	2.28521	1.43968	.291814	.787197
1980	3.70643	.625248	2.16414	2.65635	2.07592	1.42217	.261838	.755936
1985	3.92569	.65418	2.5752	2.85228	1.87477	1.40355	.231354	.724228
1990	4.16125	.687471	3.0146	3.06306	1.66354	1.38631	.201501	.693073
2000	4.87796	.819711	4.32032	3.70813	1.08922	1.37253	.151282	.639095

Table 5.6

PER CAPITA CONSUMPTION IN POUNDS

Year	Species							
	Shrimp	Crabs	Lobsters	Tuna	Salmon	Groundfish	Scallops	Oysters & Clams
1975	1.15511	.185843	.245691	2.09563	3.13142	2.19048	.0236369	4.80978
1980	1.23239	.196015	.307308	2.27357	2.84464	2.16384	.0212089	4.61877
1985	1.30529	.205085	.365678	2.44127	2.569	2.13551	.0187397	4.42503
1990	1.38362	.215522	.428074	2.62167	2.27955	2.10927	.0163215	4.23468
2000	1.62192	.256979	.613486	3.17379	1.49256	2.0883	.0122538	3.90487

MATRIX OF MAXIMUM ATTAINABLE CONSUMPTION MINUS PROJECTED PER CAPITA CONSUMPTION (IN POUNDS)

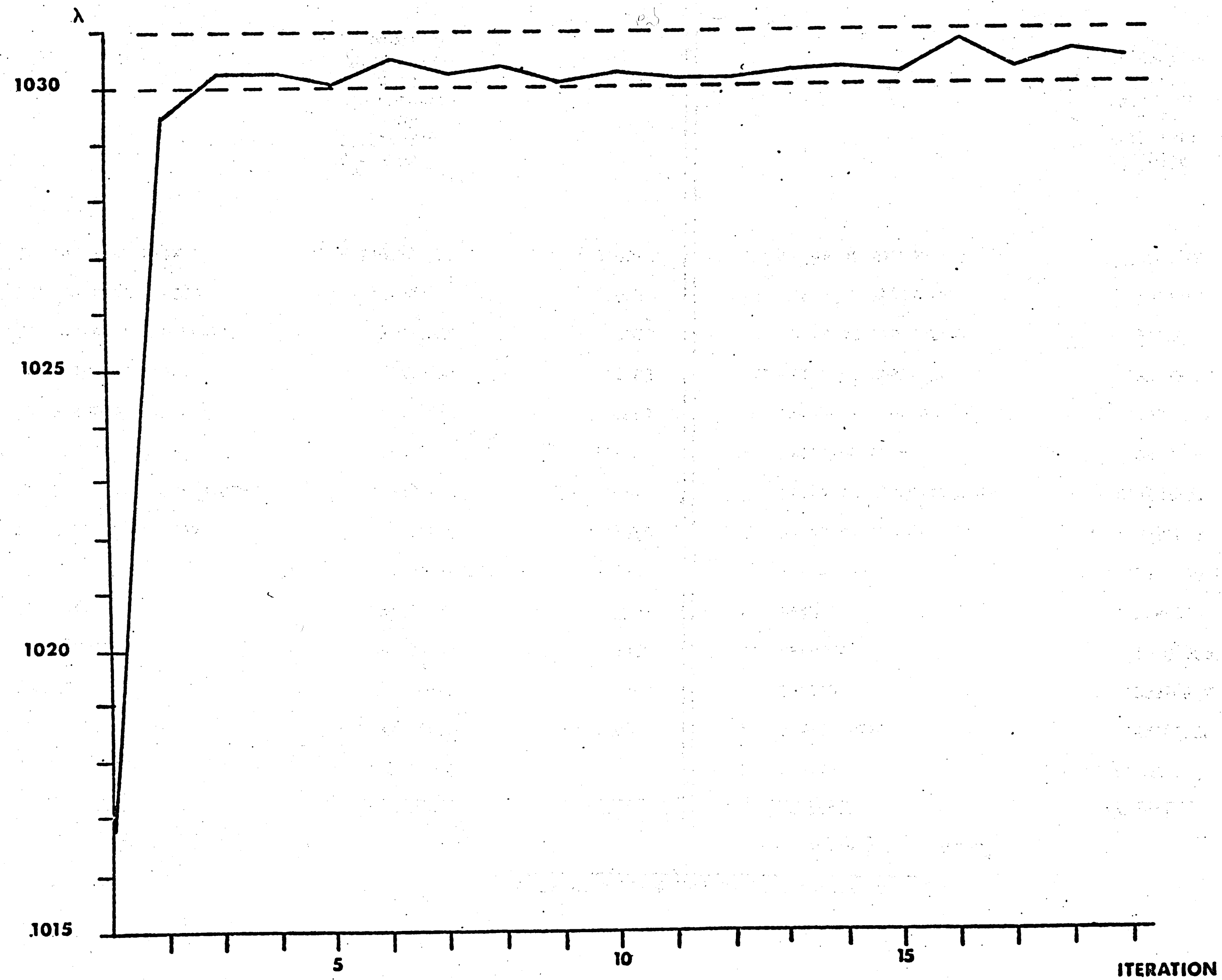
Year	Shrimp	Crabs	Lobsters	Tuna	Salmon	Groundfish
1975	.42466	.123477	.445047	1.67391	-2.927334	-.30081
1980	.24125	.092526	.337029	1.242274	-2.654264	-.40111
1985	.06522	.063261	.233563	.82894	-2.391948	-.49615
1990	-.10370	.035086	.131557	.43238	-2.114201	-.57827
2000	-.49586	-.036496	-.121127	-.48686	-1.347087	-.74187

Table B.1

CHANGE IN ESTIMATED PARAMETERS FROM ITERATION TO ITERATION

	B					C				
Iteration #	B_1	B_2	B_3	B_4	B_5	C_1	C_2	C_3	C_4	C_5
1										
2	-.00201570	.0819943	.288423	.275435	.35213200	-.0665606	-.289285	-3.1855	-4.04649	7.5878356
3	.00202864	.0820221	.288578	.275064	.35230726	-.066901	-.286846	-3.1786	-4.04759	7.579937
4	.00203114	.0820193	.28856	.275111	.35227856	-.0669884	-.287148	-3.17955	-4.04715	7.5808364
5	.00203160	.0820157	.288557	.275116	.35227970	-.0670019	-.286924	-3.17908	-4.04707	7.5800759
6	.00203190	.0820238	.288567	.275092	.35228530	-.0670114	-.287293	-3.17976	-4.04731	7.5813744
7	.00203184	.0820202	.28856	.275107	.35228096	-.0670099	-.287154	-3.17941	-4.04715	7.5807239
8	.00203188	.0820217	.288563	.2751	.35228342	-.0670109	-.287204	-3.17956	-4.04722	7.5809949
9	.00203186	.0820205	.288561	.275104	.35228264	-.0670103	-.287159	-3.17945	-4.04717	7.5807893
10	.00203182	.0820192	.28856	.275107	.35228198	-.0670092	-.287092	-3.17934	-4.04715	7.5805912
11	.00203180	.0820183	.28856	.275109	.35228090	-.0670085	-.287047	-3.1793	-4.04715	7.5805055
12	.00203180	.0820181	.28856	.275109	.35228092	-.0670083	-.287036	-3.17929	-4.04715	7.5804843
13	.00203181	.0820188	.288561	.275107	.35228139	-.0670088	-.28707	-3.17935	-4.04716	7.5805888
14	.00203183	.0820193	.288561	.275105	.35228287	-.0670094	-.287098	-3.1794	-4.04717	7.5806774
15	.00203182	.082019	.288561	.275107	.35228118	-.0670091	-.287081	-3.17936	-4.04713	7.5805801
16	.00203203	.082028	.288571	.275082	.35228697	-.0670157	-.2875	-3.18009	-4.04739	7.5819957
17	.00203186	.0820209	.28856	.275108	.35227924	-.0670107	-.287193	-3.17944	-4.04711	7.5807537
18	.00203198	.0820259	.288567	.275089	.35228612	-.0670139	-.2874	-3.17985	-4.04731	7.581539

1. Seafood
2. All other food
3. Other non-durables
4. Durables
5. Services



CONVERGENCE PATH OF λ

REGRESSION RESULTS FROM CROSS-SECTIONAL STUDY

Table 4.1 Shrimp*

Variables	Regression	T Ratio
1. Constant	- .15422808	
2. Family Size	- .38971170	- 1.996
3. Jewish	.39735955	.2346
4. Catholic	.20096034	.3430
5. Negro	.94626299	.8803
6. Income	$.57201015 \times 10^{-3}$	5.337
7. Price of Shrimp	.36276636	.7522
8. Price of Oysters/Clams	.43292527	.6944
9. Price of Tuna	1.2927260	1.133
10. Price of Lobsters	.49173035	.9758
11. Price of Crabs	- .30729344	- .5468
12. Price of Groundfish	- .34823279	- .7025
13. Price of Scallops	1.8690439	1.612
14. Price of Salmon	- 1.9728542	- 2.047

$R^2=.2105$
$F(13,131)=$ 5.229
269 observations
*Household Level

Table 4.2 Crabs*

Variables	Regression	T Ratio
1. Constant	- 2.5973228	
2. Family Size	- .51076755	- 2.095
3. Jewish	- .29550586	- .1700
4. Catholic	.16485509	.2125
5. Negro	1.0459726	.7980
6. Income	$.15292862 \times 10^{-3}$	1.453
7. Price of Shrimp	- 1.3957403	- 1.196
8. Price of Oysters/Clams	2.4533307	4.561
9. Price of Tuna	.2333424	.1770
10. Price of Lobsters	- .79732715	- 1.271
11. Price of Crabs	.37532200	.9727
12. Price of Groundfish	.90026434	1.349
13. Price of Scallops	1.4914521	1.880
14. Price of Salmon	1.8757360	1.273

$R^2=.2896$
$F(13,131)=$ 4.108
145 observations
*Household Level