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Analysis of the impact of fish imports on domestic crawfish prices and economic welfare using inverse demand systems

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ANALYSIS OF THE IMPACT OF FISH IMPORTS ON DOMESTIC CRAWFISH PRICES AND ECONOMIC WELFARE USING INVERSE DEMAND SYSTEMS

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ABSTRACT

This study is mainly intended to determine quantitatively the economic effects of crawfish imports on the domestic crawfish industry. Inverse demand systems are used to estimate the price and scale flexibility as an indicator for the effects of imports on crawfish domestic price.

A variety of algebraic forms for empirical consumer allocation models have been developed. Economic theory, however, does not provide the necessary fundamental criteria to choose *ex ante* among the alternative specifications. Bartern (1993) and Brown, Lee, and Seale (1995) examined a family of inverse demand systems, showing that the integrated demand system, in its own right, has more parameters than any of the component systems, and is, therefore, more flexible. This study also finds that among the different type of inverse demand systems the generalized inverse demand model (GIDS) is a better fit for the data used in this study.

As expected, the cross price flexibility of imported crawfish and scale flexibility in the domestic crawfish equation are shown to be negative, implying that crawfish imports have negative effect on domestic crawfish price and imports of aggregate fish also have a negative effect on the domestic crawfish price. At the same time, cross price flexibilities show either substitutability or complementarity. The Morishima elasticity of complementarity was used as a more adequate measure of interaction between commodities than the coefficients of the Antonelli matrix. The study showed that the elasticities of complementarity are all positive, implying both the tendency toward complementarity and the negativity of the own-quantity elasticities.

As the negativity of cross price flexibility of imported crawfish indicates, domestic crawfish producers will suffer economic losses from increased imports of crawfish, while the domestic crawfish consumer will be better off. Even though the economic loss to the domestic crawfish producers resulting from increases in the imports of crawfish is relatively small compared with the gains to domestic crawfish consumer welfare, the impact of imports is serious to the domestic crawfish industry because the loss is accrued to a small number of domestic crawfish processors. This study however, shows a net social welfare gain from increasing crawfish imports.

CHAPTER 1

INTRODUCTION

Louisiana leads the nation in the production of freshwater crawfish.[1] In Louisiana, the commercial crawfish industry has a long, historical background. In the beginning, the supply of crawfish was large based on wild harvest. By the end of the 1960s, farm-raised crawfish had become a common supply source. However, some farmers still catch crawfish in the Atchafalaya Basin Swamp for the live and processed markets.

In 2004, total commercial crawfish production was 78 million pounds. Of this total, 70 million pounds (90% of the total) was farm-raised with the remaining 8 million pounds being harvested naturally.

Table 1.1. Louisiana Crawfish Production in 2004

	No. of Producers	Acres	Production (lb)	Gross Farm Value ($)
Farm-Raised	1,226	118,250	69,546,680	41,728,008
Wild-Caught	1,481	-	8,267,173	4,808,939

Source: Louisiana Ag. Summary.

In 2004, 1,226 farmers produced crawfish in ponds thus ensuring the quality of the product with a total pond acreage of 118,250 (Table 1). Gross farm value of the harvest (farm-raised and wild-caught) was $46 million.

Crawfish aquaculture is an important complementary component of integrated farming systems in which rice is the principal crop. To use natural and economic resources efficiently, many rice producers double-crop crawfish in rice fields after the

[1]Other states such as Texas, California, and North Carolina produce minimal amounts of freshwater crawfish.

rice has been harvested. In the last ten years this co-cropping approach has progressed from an incidental practice to a vital economic component of many rice producers' operations. In fact, most crawfish in Louisiana are now being cultured in rice fields. The species of crawfish commercially important in Louisiana are the red swamp crawfish (*Procambarus clarki*) and the white river crawfish (*Procambarus zonangulus*).

In the U.S. market, crawfish can be sold whole and live, or as tail meat. Tail meat, in turn, can be sold fresh (chilled) or frozen. Fresh tail meat does not keep more than a couple of weeks, so the U.S. market for fresh tail meat is dominated by U.S. producers. Frozen tail meat can keep for up to a year or more, and is the focus of Chinese imports. U.S. crawfish growers are the sole supply source for the live whole crawfish market, and each year also sell some of their product for peeling (i.e. processing whole crawfish into tail meat). Crawfish tail meat is then purchased by restaurants, distributors, and retail food stores. This processed crawfish tail meat is usually sold within Louisiana or to national distributor's local outlets.

Since crawfish is a perishable product (even frozen tail meat has a limited shelf life) usage generally tracks production. Although the volume of crawfish consumed in other states is still comparatively insignificant, consumer recognition of crawfish and market acceptance has spread significantly over the past decade. U.S. per capita consumption of crawfish was approximately 0.25 pounds in 2002. However, in Louisiana per capita consumption of crawfish is approximately 10.4 pounds, as 70% of the crawfish produced in the state is consumed locally.

Up to 1999, crawfish price was relatively stationary, fluctuating from $3.00 to $3.50 per pound. However, during the 1999-2000 and 2000-2001 crawfish seasons, extreme drought conditions considerably lowered crawfish production resulting in the soaring of domestic crawfish prices. Until 1994, domestically produced crawfish had not met market challenges from imported products. For the first time, domestic production from aquaculture and capture sources was supplemented by value-added tail meat from China. Within three years, the market share of tail meat from China had increased to 87 percent (ITC, 1997). This increase caused that an antidumping petition (marketing at less than fair market value) was filed with the U.S. International Trade Commission. An investigation led to a finding of an industry being materially injured by reason of crawfish tail meat imports from China being sold in the U.S. at less than fair value. As a result, tariffs averaging 123% were established. The tariff remedy had limited impact. Severe domestic tail meat shortages resulted from two consecutive years of drought in producing areas (Kenneth, 2002). Chinese crawfish tail meat imports, heretofore under an antidumping duty, rebounded to meet domestic demand in 2000 and 2001.[2] Even after recovering normal production of crawfish, Chinese crawfish tail meat imports did not recede to their previous, lower levels. On October 28, 2000, the U.S. Congress passed the agriculture spending bill.[3] The Law instructs the U.S. Commissioner of Customs to collect certain antidumping and countervailing duties and place them in a clearing account. Once entries are liquidated, the money is transferred to a special account from which they are distributed to affected domestic producers who petition for qualifying expenditures (Schmitz and Seale, 2004).

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[2]In September 1997, U.S. International Trade Commission determined that an industry in the United States was materially injured by reason of imports crawfish tail meat from China that were sold at less than fair value. On September 15, 1997, U.S. Commerce issued an antidumping duty order on subject imports of crawfish tail meat from China.

[3]Public Law 106-387, which attached the Continued Dumping and Subsidy Offset Act (CDSOA) as amendment Title X by Senator Robert Byrd of West Virginia as part of the Agricultural, Rural Development, Food and Drug Administration and Related Agencies Appropriation Act of 2001.

The so-called "Byrd Amendment" effectively empowers domestic producers and processors, who successfully petition the U.S. government to impose antidumping and countervailing duties on competing imports, to keep the proceeds of those tariffs. For a company to be eligible for payouts, it must prove that it successfully litigated an antidumping and countervailing duty case against a specific industry in a specific country. Companies that did not participate in the original antidumping duty case do not receive any of the collected funds. Table 1.2 and 1.3 show CDSOA disbursements for food products and for crawfish tail meat from China, respectively (Schmitz and Seale, 2004).

On the basis of the record developed in the subject five-year review, the Commission determined in August 2002 that revocation of the antidumping duty order on crawfish tail meat from China would likely lead to the continuation or recurrence of material injury to an industry in the United States within a reasonably foreseeable time.

1.1. Research Problem

Even though the crawfish industry in Louisiana has proven its' economic potential, many challenges remain. Competition from imports associated with low market price and World Trade Organization (WTO) regulation are becoming increasingly important for the domestic crawfish industry.[4] Although the imported products are flowing into the domestic market through different agents or market channels,

[4]U.S. trading partners react vigorously against the CDSOA. On July 21, 2001, Australia, Brazil, Chile, the European Communities, India, Indonesia, Japan, Korea, and Thailand requested that the WTO form a panel to investigate the CDSOA with respect to U.S. obligations under Article 18.1 of the WTO Antidumping Agreement (AD) and Article 32.2 of the WTO Agreement on Subsidies and Countervailing Measures (SCM). The panel found against the U.S. on the CDSOA payments and recommended that the CDSOA be repealed. On October 18, 2002, the U.S. appealed the ruling to the WTO Appellate Body, but on January 16, 2003, the Appellate Body confirmed that the CDSOA was incompatible with WTO rules. In January 2004, the EU and other nations asked for WTO permission to take retaliatory action against the U.S. because of its failure to repeal the amendment.

Table 1.2. CDSOA FY 2001-2003 Disbursements for Food Products ($1000)

Case Number	Case Name	FY2001	FY2002	FY2003	Total
A-475-818	Pasta/Italy	17,533	4,674	1,730	23,938
A-570-848	Crawfish tail meat/China	-	7,469	9,764	17,233
A-549-813	Canned pineapple/Thailand	1,792	531	5,395	7,718
C-475-819	Pasta/Italy	2,480	2,528	379	5,387
A-533-813	Preserved mushrooms/India	171	2,155	1,326	3,652
A-351-605	Frozen concentrated orange juice/Brazil	-	1,175	0	1,176
A-560-802	Preserved mushrooms/Indonesia	83	443	524	1,050
A-570-831	Fresh garlic/China	25	536	342	903
A-337-803	Fresh Atlantic salmon/Chile	-	173	644	817
A-337-804	Preserved mushrooms/Chile	-	-	170	170
A-403-801	Fresh and chilled Atlantic salmon/Norway	46	59	18	123
C-403-802	Fresh and chilled Atlantic salmon/Norway	18	29	7	54
C-507-601	Roasted in-shell pistachios/Iran	-	-	42	42
A-301-602	Fresh cut flowers/Columbia	33	-	-	33
A-570-851	Preserved mushrooms/China	-	20	12	32
A-570-863	Honey/China	-	-	29	29
C-408-046	Sugar/EU	8	17	0	26
C-489-806	Pasta/Turkey	7	9	8	24
A-489-805	Pasta/Turkey	11	4	-	15
A-570-855	Non-frozen apple juice concentrated/China	-	1	6	8
A-507-502	Raw in-shell pistachios/Iran	-	-	5	5
A-357-812	Honey/Argentina	-	-	0	0
C-357-813	Honey/Argentina	-	-	0	0
	Food Total	22,209	19,824	20,402	62,434
	Grand Total	231,202	329,871	190,247	751,320

Source: U.S. Customs Service.

Table 1.3. CDSOA Disbursements for Crawfish Tail Meat from China, FY2002-2006
Antidumping Case Number A-570-848 ($1000)

Claimant	Amount Paid				
	2002	2003	2004	2005	2006
Atchafalaya Crawfish Processors	793	1,367	894	256	535
Seafood International Distributors	707	1,051	637	192	373
Catahoula Crawfish	620	910	607	171	327
Prairie Cajun Wholesale Seafood Dist.	517	734	461	123	245
Bayou Land Seafood	420	629	464	130	252
Basin Crawfish Processors	0	593	277	81	171
Acadiana Fishermen's Co-Op	318	583	397	113	227
Crawfish Enterprises, Inc.*	399	487	837	54	117
Bonanza Crawfish Farm	313	460	314``	92	199
Riceland Crawfish	320	411	330	107	271
Cajun Seafood Distributors	319	407	327	98	202
Randol's Seafood & Restaurant*	305	349	260	77	163
Choplin Seafood	211	278	201	62	119
Carl's Seafood	219	255	161	43	82
Sylvester's Processors	219	249	148	37	97
Blanchard Seafood, Inc.*	209	217	210	58	113
Harvey's Seafood	165	203	141	40	79
Louisiana Premium Seafoods	163	150	70	0	26
Schexnider Crawfish	0	137	64	14	0
Phillips Seafood	95	109	57	14	31
C.J.'s Seafood & Purged Crawfish	374	80	437	140	276
Arnaudville Seafood	36	46	41	12	21
Teche Valley Seafood	48	45	23	5	11
A&S Crawfish	70	15	0	0	0
Clearwater Crawfish Farm	0	3	0	0	1
L.T. West	238	0	215	96	224
Louisiana Seafood	200	0	217	63	0
Bellard's Poultry & Crawfish	106	0	24	1	2
Becnel's Meat & Seafood	68	0	0	0	0
Lawtell Crawfish Processors	17	0	0	0	0
Brown Aubrey	0	0	0	119	245
Dugas Allen J	0	0	369	0	136
TOTAL for A-570-848	7,469	9,764	8,183	2,198	4,545

Source: U.S. Customs Service.
* Indicates member of the Crawfish Processors Alliance (CPA).

all imported products are consumed indiscriminately with domestically produced goods. As a result of the massive imports of Chinese crawfish, major distortions occurred in the domestic market because price is the strongest motivation among many determining factors that influences a consumer's willingness to purchase these goods. However, domestic prices of these goods are typically higher than those prices in major exporting countries due to the relatively high cost of production. The low-price imported goods force domestic producers to reduce production or go out of business. However, domestic crawfish consumption has increased constantly because of the relative health benefits related to Selenium and Vitamin B12 and/or low price of the product. Furthermore, aquaculture products, like crawfish, are increasing in importance as a source of protein along with red meat and chicken.

Louisiana's crawfish industry has high economic value. Many farmers and processors are producing not only crawfish meat but also value added products with crawfish as one of the main ingredients. Such economic activities are not only providing safe jobs and high quality foods for what people demand increasingly, they also serve to reinvigorate Louisiana's rural communities. A number of consumers and producers of crawfish are clearly involved in these economic activities (Harrison et al, 2003).

As this discussion suggests, Louisiana's crawfish industry is facing strong competition from low-priced imports and an increase in imports of these goods affects not only domestic consumers but also domestic producers and processors. As a result, in order to encourage the crawfish industry, it is necessary to assess the economic impacts these imports have had on the domestic crawfish industry in Louisiana.

1.2. Justification

Gorman's study (1959) postulated that the price of fish depends, in part, on the quantity consumed (or supplied) of the own good and in part on the quantities available of the other related goods as well as real income. Since an increase in fish imports increases total supply, increased imports might affect domestic price by which domestic crawfish consumers and producers' welfare could be affected. In fact, domestic crawfish prices are exhibiting instability especially after 2000 and 2001, along with varying imports of crawfish and other related fishery products. The purpose of this study is to focus on the downstream effects of crawfish imports and the other related fishery products such as catfish, shrimp, and oysters which are expected to compete with crawfish. This study will accomplish this goal by using a system of inverse demand equations in which price variations are explained by functions of quantity variations.

The justification of the use of inverse demand systems for fish was well illustrated by Barten and Bettendorf (1989) as follows:

"For certain goods, like fresh vegetables or fish, supply is very inelastic in the short run and the producers are virtually price takers. Price taking producers and price taking consumers are linked by traders who select a price which they expect clears the market. In practice this means that at the auction the wholesale traders offer prices for the fixed quantities which, after being augmented with a suitable margin, are sufficiently low to induce consumers to buy the available quantities. The traders set the prices as a function of the quantities. The causality goes from quantity to price."

In developing an inverse demand system for empirical price and welfare analysis, the system should meet the curvature conditions implied by microeconomic theory. Holt and Bishop (2002) summarized the curvature conditions required as follows: (1) the direct utility function should be quasi-concave in quantities; (2) the indirect utility function should be quasi-convex in prices; and (3) the expenditure function should be concave in prices. If an inverse demand system sufficiently satisfies these curvature conditions, then the inverse demand system can be applied to welfare effect analysis associated with a price change.[5]

In order to analyze the downstream effects of increased imports of crawfish, this study is conducted on the basis of the economic theory related to a theoretically consistent, inverse demand system in which the prerequisite curvature condition is sufficiently satisfied. In an inverse demand function, price is the endogenous variable as opposed to a traditional demand function, where quantity is the endogenous variable.[6] An inverse demand system is more desirable for analysis of demand for perishable fishery products because even though these products can be stored either in a frozen state or as processed goods, the life span of these products should be limited.

1.3. Objectives

1.3.1. General Objectives

This study has the following main objectives:

1. To provide a theoretical and practical way of determining the impacts on domestic price given a change in import volume; and,
2. To obtain measurements of welfare changes in the inverse demand system and provide exact welfare measures associated with changes in imports.

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[5]Many economists showed that in practice encountering situations where curvature conditions hold spontaneously and globally are rare. The result is that researchers have increasingly considered model specifications that allow these restrictions to be imposed either globally or locally during estimation. See, respectively, Barten and Geyskens (1975), Barnett (1983 and 1985), Gallant and Golub (1984), Barnett and Lee (1985), Barnett, Lee, and Wolfe (1987), Chalfant, Gray, and White (1991), Brenton (1994), Koop, Osiewalski, and Steel (1994), Ramajo (1994), Terrel (1996), Moschini (1998), Ryan and Wales (1999), Holt and Bishop (2002), and Wong and Mclaren (2005).

[6]The inverse demand equation is defined as follows: $p_i = f(q)$.

The traditional demand equation is defined as follows: $q_i = g(p)$.

1.3.2. Specific Objectives

The specific objectives of the study are as follows:

1. To illustrate the theoretical basis of using price and scale flexibilities to describe how these concepts can be used as a measure of quantity's impact on price;
2. To estimate and compare empirical scale, compensated, and uncompensated flexibilities for crawfish by using Generalized Inverse Demand System (GIDS) and four different inverse demand systems, i.e., Differential Inverse Rotterdam Demand System (DIRDS), Differential Inverse Almost Ideal Demand System (DIAIDS), Differential Inverse Demand of Central Bureau of Statistics (DICBS), and Differential Inverse Demand of National Bureau of Research (DINBR);
3. To estimate empirical approximations versus exact measures of consumer welfare change in quantity space by using the estimated price and scale flexibilities; and,
4. To develop a practical way in which to measure the crawfish producer welfare changes associated with variations in price and quantity.

1.4. Research Procedure

1.4.1. Objective One

Like Hicksian decomposition in traditional demand systems, price change in an inverse demand system can be decomposed into two parts: 1) substitution effect and 2) scale effect in Antonelli's decomposition.[7] Since price change in Antonelli's decomposition is explained by changes in not only quantity but also real purchasing power, the inverse demand system should be formulated to explain both effects.

[7]Kim (1997) showed the Antonelli decomposition of the price effect of a quantity change into the substitution and scale effects.

In an inverse demand system, compensated price flexibility describes the substitution effect and scale flexibility explains the income effect. The uncompensated price flexibility is the sum of compensated price and scale flexibilities.

The objective will be achieved by using a family of inverse demand systems:

$$w_i d\ln p_i = g_i d\ln Q + \sum_j g_{ij} d\ln q_j \tag{1.1 GIDS}$$

$$w_i d\ln p_i = h_i d\ln Q + \sum_j h_{ij} d\ln q_j \tag{1.2 DIRDS}$$

$$dw_i = c_i d\ln Q + \sum_j c_{ij} d\ln q_j \tag{1.3 DIAIDS}$$

$$w_i d\ln \frac{p_i^*}{P} = c_i d\ln Q + \sum_j h_{ij} d\ln q_j \tag{1.4 DICBS}$$

$$dw_i - w_i d\ln Q = h_i d\ln Q + \sum_j c_{ij} d\ln q_j \tag{1.5 DINBR}$$

where p_i is the normalized price of the ith good, p_i^* is the nominal price of the ith good, $w_i = p_i q_i$ is the ith good's budget share, $d\ln Q$ is a differential Divisia quantity index, and $d\ln P$ is a differential Divisa price index.[8,9] In equations (1.1) – (1.5), g_i, h_i, and c_i represent the move from one difference surface to another, implying scale effect and that g_{ij}, h_{ij}, and c_{ij} represent a movement along the same indifference surface, implying substitution effect.

[8]A Differential Divisia quantity index: $d\ln Q = \sum_i w_i d\ln q_i$.

[9]A Differential Divisia price index: $d\ln P = \sum_i w_i d\ln p_i$.

1.4.2. Objective Two

1.4.2.1. Consumer Welfare

The use of the inverse demand systems is motivated by our interest in the price and welfare effects of imported crawfish products. Consumer welfare can be measured by consumer's surplus of uncompensated inverse demand and compensating variation or equivalent variation calculated by compensated flexibility. As the uncompensated flexibility overestimates the quantity effect on price, in which the quantity effect includes both substitution and scale effects, consumer surplus is only an approximated measurement. However, compensated flexibility measures exactly the quantity effect in which the scale effect can be separated from the substitution effect. As a result, compensating variation will be used in this study to exactly measure the effect of imports on consumer welfare.

1.4.2.2. Producer Welfare

As the production and profit of domestic crawfish processors might be affected by imports of crawfish and/or other related fishery products, depending on positive or negative impacts of the imports on domestic crawfish price, the welfare effect of the domestic crawfish processor could be easily measured through dual cost and profit functions. To measure quantitatively the welfare impact of the domestic crawfish processor in quantity space, flexibilities will be used in the profit equation of domestic producer of q_j. For example, the change in crawfish imports can affect not only the domestic crawfish price but also the domestic production because domestic production can be affected by domestic price. The change then in profit represents producer's welfare impact.

1.5. Data Requirement

The fish species represented are five types of commercial fish: domestic crawfish, imported crawfish, catfish, shrimp, and oysters. There are wide ranges in the supplied quantities of each type of fish. This is especially true with domestic crawfish. Combined, the captive and cultured harvests of domestic crawfish ranged from 27 to 56 thousand MT during the 1990's. The wide range in such a short time period reflects the production swings in the capture fishery. During this period, the range for capture supply was 8 to 32 thousand MT. Although varied, culture sources were more reliable, producing from 16 to 28 thousand MT annually. While variation in the capture supply is mostly rooted in fluctuating water levels in rivers, the culture supply variation is more reflective of the producers response to prices and conditions in the rice industry (Kenneth, 2002).

The data refers to the fish commercially available in the U.S. market through domestic supply and imports, from 1980 to 2005. The data are annual time series consisting of prices and quantities (see Appendix II). Let q_i^* denote the quantity variable of i^{th} fishery good. Conversion of q_i^* into a normalized quantity, q_i, which is the requisite form utilized in inverse demand systems, is calculated as:

(1.6) $$q_i = \frac{q_i^*}{q_{i,mean}},$$

where $q_{i,mean} = \dfrac{\left(\sum_{i=1}^{n} q_i^*\right)}{N}$

$q_i > 1$, if $q_i^* > q_{i,mean}$,

$q_i = 1$, if $q_i^* = q_{i,mean}$, and

$q_i < 1$, if $q_i^* < q_{i,mean}$.

Now, let p_i^* denote the price variable of i^{th} fishery good. Then, total expenditure on the products included in the analysis is calculated as follows:

(1.7) $$m = \sum_{i=1}^{n} p_i^* \cdot q_i \ .$$

To get the normalized price, p_i, p_i^* is divided by m as follows:

(1.8) $$p_i = \frac{p_i^*}{m}.$$

Note that p_i is the same for wholesale, retail, and processor prices if the trader's marginal is proportional to the price. Then, the budget share of each fish, w_i, is obtained through multiplying p_i by q_i as follows:

(1.9) $$w_i = p_i \cdot q_i, \text{ where } \sum_{i=1}^{n} w_i = 1.$$

1.6. Outline of Dissertation

This work accomplishes its' two main objectives through a "traditional-style" dissertation. A comprehensive literature review is presented in chapter two. Chapter three will discuss the economic theory related to inverse demand systems. Chapter four will describe the econometric skills required, including a restricted system estimator, homogeneity, adding up, symmetry, singularity, autocorrelation, and endogeneity issues encountered in estimating price and scale flexibilities. Empirical results and discussion will be presented in chapter five, with chapter six serving as an overall summary.

CHAPTER 2

LITERATURE REVIEW

Many theories are available to explain the benefits of free trade for both importing and exporting countries – see Krugman and Obstfeld (1991), Ohlin (1933), Ricardo (1817), and Smith (1776). While both nations can benefit from free trade as long as each nation has a comparative advantage in the production of one commodity, lower-priced imported goods often reduce the domestically produced goods' price in the importing country so that the importing country's producers could be negatively impacted with a reduction in profits. In the early 1990s, the crawfish processing business in Louisiana was a well-established and profitable component of the state's economy. Domestic crawfish price was stable, hovering at around $3.50 per pound during that time. However, with the introduction of increased Chinese crawfish tail meat imports into the domestic market, domestic price for crawfish became more unstable. For example, the domestic monthly price of crawfish has fluctuated from $1.92/lb. to $6.06/lb. during 2001-2004. As a result, Louisiana crawfish processors have suffered from price instability attributed to the increased imports of lower-priced Chinese crawfish tail meat.

The use of econometric models to analyze fish markets provides a quantitative approach for structural, forecasting, and policy evaluation. Given that theoretical concepts of fish price formation, inverse demand system, compensating and equivalent variation, and price and scale flexibilities are closely related to construct structural econometric model for the U.S. crawfish market, the relevant literature review needs to include studies that model inverse demand systems, that measure welfare in quantity space, and that examine developments in econometric methods applied to these problems.

2.1. Fish Price Formation

Gorman (1959) proposed that the price of fish partially depends on specific factors, stipulating that price is a function of quantity consumed and income, and in part on the shadow prices of basic characteristics shared by all types of fish. The biological nature of the production process of fish results in many fishery products being produced annually or only at regular time intervals. Some of these products are perishable or semi-perishable, and cannot be stored for long periods. The products must be consumed within a certain period of time. Hence the situation results in fixed supply and a given of demand for a specific time period. In the short term, the level of production cannot be changed. For such goods, the causality is from quantity to price.

Elasticities long have been used as the basic conceptual tools both in demand theory and in estimation. However, agricultural economists often find that price flexibility is more useful and easier to measure, especially in whole market situations. Price flexibility is the percentage of change in the price of a commodity, associated with an isolated one percent change in the quantity or in a related variable. This term, used in this way, was introduced in 1919 by H. L. Moore in his pioneering article, "Empirical Laws of Demand and Supply and the Flexibility of Prices." Moore drew attention to price flexibility in order (1) to focus on price phenomena from the producers' viewpoint and (2) to provide analytic content to his cotton-demand-curve estimates. The concept's usefulness grew out of Moore's observation that, although individuals make quantity decisions based on given prices, market supplies of many agricultural products are so fixed in the short run that prices must bear the entire adjustment burden. Consequently, the amount by which market prices change in response to output changes between production periods is particularly important in the farm sector (Houck, 1966).

Houck (1966) explained the relationship of direct price flexibilities to direct price elasticities. He showed that it is frequently easier to estimate direct and cross price flexibilities rather than price elasticities in agricultural economics research. However, elasticity estimates may be needed or wanted. His paper showed that, under rather general conditions, the reciprocal of the direct price flexibility is the lower absolute limit of the direct price elasticity. The departure of the true price elasticity from the flexibility reciprocal depends on the strength of the cross effects of substitution and complementarity with other commodities.

Huang (1994) examined the relationships between price elasticities and price flexibilities with emphasis on comparing differences between a directly estimated demand matrix and an inverted demand matrix. He concluded that since the common practice of inverting an elasticity matrix to obtain measures of flexibilities or vice versa can cause sizable measurement errors, only directly estimated flexibilities should be used to evaluate price effects of quantity changes.

Eales (1996) disagreed with Huang's recommendation for three reasons. First, Huang inverted matrices from separable subsystems. This, in general, can be expected to be misleading because the conditional and unconditional elasticities derived from a separable ordinary demand system are not equal. Second, inversion of sensitivity matrices from conditional demand may or may not produce good estimates of unconditional sensitivities. That is, if one estimates an ordinary meat demand system and inverts the elasticity matrix, it cannot, in general, be expected to produce good estimates of the unconditional meat flexibilities and vice versa. Finally, expenditures cannot be viewed as predetermined in conditional demand systems. He argued that one should not employ directly estimated elasticities unless one is willing to believe that those estimates are consistent, i.e., prices and expenditure are predetermined.

However, according to Huang's reply to Eales' comment, there are at least two drawbacks in obtaining a matrix of demand elasticities by inverting a directly estimated price flexibility matrix or vice versa. He indicated that in the process of inversion, the point estimates must be treated as pure numbers representing the true parameters, ignoring the stochastic properties of the estimates. Another drawback is that the inverted results are quite sensitive to the numerical structure (for example, existence of a singularity problem) of a demand matrix being inverted, and that could cause unstable results. Due to the stochastic properties in estimating elasticities or flexibilities by adopting time series data, the consistency between direct and indirect flexibilities is not guaranteed.

The difference between the estimations of both stochastic parameters can be seen in the following examples. Assume that there are two goods, q_1 and q_2, and their respective prices, p_1 and p_2, as well as income, *m*. One can estimate both linear regression models for the inverse and direct demand equations. First, the inverse demand statistical equations are shown as follows:

(2.1) $\ln p_1 = \beta_{10} + \beta_{11}\ln q_1 + \beta_{12}\ln q_2 + \beta_{13}\ln m + \varepsilon_1$

(2.2) $\ln p_2 = \beta_{20} + \beta_{21}\ln q_1 + \beta_{22}\ln q_2 + \beta_{23}\ln m + \varepsilon_2$

where ε_i is the random error term. According to the assumption of statistical regression procedure, $E(\varepsilon) = 0$ and q and ε are independent, such that $E(q \cdot \varepsilon) = 0$ where q

represents the set of quantities (q_1 and q_2). Second, the direct demand statistical equations are shown as follows:

(2.3) $\ln q_1 = \alpha_{10} + \alpha_{11} \ln p_1 + \alpha_{12} \ln p_2 + \alpha_{13} \ln m + e_1$

(2.4) $\ln q_2 = \alpha_{20} + \alpha_{21} \ln p_1 + \alpha_{22} \ln p_2 + \alpha_{23} \ln m + e_2$

where e is the random error term. According to the assumption of statistical regression procedure, $E(e) = 0$ and p and e are independent, such that $E(p \cdot e) = 0$ where p represents the set of prices (p_1 and p_2). Using the four different equations, the relationships among parameters can be estimated, representing direct flexibilities in (2.1) and (2.2) and direct elasticities in (2.3) and (2.4). Furthermore, it can be shown that $\beta_1 \neq \frac{1}{\alpha_1}$ and $\beta_2 \neq \frac{1}{\alpha_2}$.

In addition to this, assume that $p = q'\beta + \varepsilon$. p and q are vectors of prices and quantities. We can then rewrite this equation as $q = p'\alpha + e$, where $\alpha = \frac{1}{\beta}$, and $u = \frac{-1}{\beta}\varepsilon$. Further manipulation allows the following to be obtained:

(2.5) $\alpha = (p'p)^{-1} p'q$

(2.6) $\alpha = (p'p)^{-1} p'(p\alpha + e)$

(2.7) $\alpha = (p'p)^{-1} p'p\alpha + (p'p)^{-1} p'e$

(2.8) $\alpha = (p'p)^{-1} p'p\left(\frac{1}{\beta}\right) + (p'p)^{-1} p'\left(\frac{-1}{\beta}\varepsilon\right)$

(2.9) $\alpha = \frac{1}{\beta} - (p'p)^{-1} p'\left(\frac{1}{\beta}\varepsilon\right)$

If p and ε are correlated, then $\alpha \neq \frac{1}{\beta}$; however, if p and ε are not correlated, the direct price flexibility is equal to the reciprocal of the direct price elasticity.

In empirical modeling, direct price flexibility is derived from the inverse demand function in which price is a function of the quantity supplied of own commodity, related commodities, and a shift variable. In contrast, indirect price flexibility is acquired utilizing the ordinary demand function, in which quantity is a function of the price of the commodities and income. As shown in equations (2.1) to (2.9), the reciprocal of the flexibility (elasticity) estimated in an empirical model is not always a good approximation of the elasticity (flexibility) since different variables are held constant in the two different estimations. Even though the critical issue of price flexibility is unresolved, Houck (1966), Huang (1994), and Eales (1996) ascertained the benefits of using price flexibilities to empirically evaluate price effects of quantity.

Price flexibility is the percentage change in price resulting from a particular change in quantity with all other factors held constant.[10] If demand is inelastic, then the absolute value of the indirect price flexibility coefficient is likely to be greater than one. A flexible price is consistent with an inelastic demand. In other words, a small change in quantity has a relatively large impact on price. If demand is elastic, then the absolute value of the price flexibility coefficient is likely to be less than one. An inflexible price is consistent with an elastic demand.

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[10]The price flexibility coefficient (*f*) is defined as follows: $f = \frac{dp}{dq} \cdot \frac{q}{p}$.

The cross flexibility of i with respect to j is the percentage change in the price of commodity i in response to an one percent change in the quantity of commodity j, other factors remaining constant.[11]

The cross flexibility based on the quantity variable of a substitute is expected to be negative. This is in contrast to cross elasticities for substitutes that usually are positive. A larger supply of a substitute results in a lower price for the substitute, which in turn results in a decline in demand for the first commodity. The lower demand implies a reduction in price. Hence, a larger supply of the substitute (commodity j) reduces the price of the commodity under consideration (commodity i).

The price flexibility of income is the percentage change in price in response to an one percent change in income, other factors remaining constant.[12] The flexibility of income is typically expected to be positive. Price moves directly with the shift in demand. A higher income implies a larger demand, in turn, suggesting a higher price for any given level of quantity.

2.2. Modeling Inverse Demand System

In recent years, there has been increasing interest in inverse demand systems based on different objectives. Key objectives are (1) the specification of inverse demand system for which curvature conditions implied by economic theory are maintained, (2) the quantitative estimation of price effects of quantity change, and (3) quantity-based welfare measures. Most inverse demand systems use normalized price as a function of

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[11]The algebraic relationship of cross price flexibility is as follows: $f_{ij} = \frac{dp_i}{dq_j} \cdot \frac{q_j}{p_i}$.

[12]The algebraic relationship of income flexibility is as follows: $f_{im} = \frac{dp_i}{dm} \cdot \frac{m}{p_i}$.

quantities demanded in inverse demand systems.

The curvature conditions require that (1) the direct utility function should be quasi-concave in quantities, (2) the indirect utility function should be quasi-convex in prices, or (3) the expenditure function should be concave in prices. The curvature conditions of inverse demand systems are required to consistently satisfy microeconomic theory of demand system. Like in the direct demand systems, however, in practice encountering situations where curvature conditions hold spontaneously and globally are rare, which is one reason about why the empirical estimation is not consistent with what we expect under microeconomic theory of demand system.

In the seminal stages of inverse demand systems development, economists adopted the theoretically well-developed direct demand system from which the inverse demand system is derived, basing their reasoning on the same theoretical conditions of adding up, homogeneity, and symmetry. The contribution of this effort was to parameterize both direct and inverse demand systems such that comparisons between the two systems could be made.

Anderson (1980) established some theoretical properties of inverse demand systems which aid in their interpretation and facilitate calculations related to them. He introduced the notion of scale elasticity, which is shown to play for inverse demand systems much the same role that income elasticity does for direct demand systems. It is used in a decomposition of Antonelli effects which is analogous to the Slutsky equation for direct demand systems. He explained the duality process for uncompensated elasticity, expenditure elasticity, compensated elasticity, quantity elasticity (price flexibility), and scale elasticity simply given utility maximization and the knowledge of budget share.

Barten and Bettendorf (1989) developed differential inverse demand systems to parameterize eight different fishery quantity variables. Specifically, they developed (1) the Inverse Rotterdam Demand System (IRDS) from the Rotterdam Demand System (as developed by Barten (1964) and Theil (1965), (2) the Inverse Almost Ideal Demand System (IAIDS) from the Almost Ideal Demand System (AIDS) (as developed by Deaton and Muellbauer (1980)), and (3) the Inverse Central Bureau of Statistics (ICBS) from the Central Bureau of Statistics (CBS) which was first proposed by Laitinen and Theil (1979). Through using these three different inverse demand systems in application for a fishery demand system, they provided insight into the interpretation of the coefficients.

Neves (1994) proposed the National Bureau of Research (NBR) direct demand system, which has an inverse National Bureau of Research (INBR). The INBR combines IAIDS quantity effects with an IRDS scale effect.

Brown, Lee, and Seale (1995) developed a generalized inverse demand system, which combined the features of the IRDS and IAIDS. The synthetic inverse demand system nests the inverse analogs of all of the models nested within the generalized ordinary demand system.

Moschini and Vissa (1993) showed the alternative of using a direct approximation to mixed demands, in which prices of some goods are predetermined such that the respective quantities demanded adjust to clear the market, whereas for the remaining set of goods quantities supplied are predetermined and prices must adjust to clear the market. The proposed mixed demand system was illustrated with an application to the Canadian meat market. The fact that Canada has virtually free trade in beef and pork, whereas the supply of chicken is restricted, indicates that a mixed demand approach is more appealing in this case.

Eales, Durham, and Wessells (1997) modeled Japanese fish demand using both ordinary and inverse demand systems, each of which nests a number of competing specifications. Results indicated that the inverse demand systems dominate the ordinary demand systems in forecasting performance and in non-nested tests.

Park and Thurman (1999) showed that scale flexibilities in inverse demand systems describe how marginal valuations change with expansions in the consumption bundle. Such effects clearly are related to income elasticities in direct demand systems. However, the connection is not so close as it first appears. They argued that the link between scale flexibilities and income elasticities is tight only if preferences are homothetic, a situation where neither measure is interesting, or if all elasticities of substitution are unitary. They illustrated the relationship between the two measures in a coordinate system focusing on how marginal rates of substitution change with consumption scale and proportion.

Beach and Holt (2001) introduced inverse demand systems that include quadratic scale terms. These systems are similar to regular quadratic demand systems introduced by Howe, Pollak, and Wales (1979). The models developed were used to estimate inverse demand equations for finfish landed commercially in the South Atlantic from 1980-1996. Overall, they showed that including quadratic terms in inverse demand specifications offers an improvement in modeling systems in which quantities are taken as exogenous.

Holt and Bishop (2002) proposed the normalized quadratic distance function, which is similar to the normalized quadratic expenditure function of Diewert and Wales

(1988a) as a new inverse demand system. Aside from being able to maintain concavity in quantities globally, the resulting specification is also flexible. In addition, to obtain more parsimonious specifications, they applied the rank reduction procedures of Diewert and Wales (1988b) to the model's Antonelli matrix. They illustrated the techniques by estimating a system of inverse demands for bi-monthly fish landings, 1971-1991, for U.S. Great Lakes ports. To illustrate the model's usefulness, exact welfare measures associated with catch restrictions are derived.

Park, Thurman, and Easley Jr.(2004) used the combined inverse demand systems from IRDS, IAIDS, ICBS, and INBR to measure the welfare loss of fish catch restrictions. Unlike single equation models, the system-wide approach does not exclude substitution possibilities and includes interactions that are potentially important for understanding fish consumption patterns and price determination. They applied the estimated system by analyzing welfare measures of quantity restrictions: catch restrictions in the grouper and snapper complex off the southeast coast of the U.S.

Wong and Mclaren (2005) proposed a new approach, a distance function approach, to the specification of inverse demand systems for empirical estimation of fishery products that is directly and weakly separable from other commodities. The separability assumption needs to be held with an aim of keeping the estimation process manageable by merely dealing with certain aspects of the static demand model. They advocated a more general use of the distance function in specifying regular and estimable inverse demand systems. Note that they only focus on the type of distance functions for which it is not necessary to have closed functional forms for the inverse uncompensated demand functions, nor for the direct utility function. Their results indicated that the distance function approach is a promising tool of empirical analysis of inverse demand systems subject to tight theoretical conditions. This opens up a further avenue for ultimately obtaining systems of inverse demand functions.

Matsuda (2005) provided a new interpretation of the scale effects in differential inverse demand systems. A scale curve is defined as a curve that shows how the expenditure share of a good or service changes as the consumption level changes. It was shown that Brown, Lee, and Seale's synthetic model has the same scale effects as do the Box-Cox scale curves. In this light, their model is not a mere composite but a model in its own right. The empirical illustration given for fresh food demand in Japan has suggested that none of the four nested models, IRDS, IAIDS, ICBS, and INBR is adequate and that there are some nontrivial differences between their elasticity estimates and those in the synthetic model. The data have preferred the synthetic model and not supported either linear or logarithmic linear scale curves.

2.3. Welfare Measurements

Most welfare analyses are concerned with the welfare effects of price changes. There are, however, many situations in which policy options are directly related to quantity changes. The welfare effects of price changes are analyzed with the direct demand system in which commodity quantities are determined as functions of their prices. The welfare effects of quantity changes, on the other hand, are associated with the inverse demand system in which commodity prices are dependent on their quantities. In conventional welfare analysis of price change, prices are taken to be exogenous or predetermined, while quantities are endogenous. In contrast, in welfare analysis of quantity changes, quantities are exogenous, while prices are endogenous. Price-based or dual welfare measures are relevant when there are well-functioning competitive markets and quantities are fully adjusted to changes in prices; on the other hand, quantity-based or primal welfare measures are useful in situations where there are constraints on commodity quantities, or when transaction costs impede consumers from fully adjusting to changes in prices (Kim, 1997).

The choice between price- and quantity-based welfare measures is empirical, and proper measurement of welfare effects requires the knowledge as to which variable – price or quantity – is exogenous. For individual consumers, it may be reasonable to assume that the supply of commodities is perfectly elastic, and therefore prices can be taken as exogenous. But this assumption may not be tenable for consumers in the aggregate or if highly aggregated economy-wide data are used to estimate demand relations. At the aggregate level, quantities (rather than prices) are viewed more properly as being exogenous. Although individual consumers make their consumption decisions based on given prices, the quantities of commodities are predetermined by production at the market level and prices must adjust so that the available quantities are consumed (Kim, 1997).[13,14] This implies that although price-based measures are useful for analyzing the welfare of individual consumers, quantity-based measures may be more appropriate at the aggregate level.[15] Given the fact that most of the consumer demand studies based on time-series data involve the estimation of aggregate demand functions, there is a clear need for the inverse demand system and hence welfare analysis of quantity changes in empirical analysis. Moreover, while these results hinge on competitive behavior, quantity-based measures are essential for analyzing the welfare effects for non-competitive firm or industry behavior (Kim, 1997).

Quantity-based welfare measures are not totally new. Indeed, consumer surplus is often discussed for changes in price or quantity for a single commodity, and the Marshallian surplus measure (together with producer surplus) for quantity changes is used to analyze social welfare (or deadweight loss) or the welfare properties of market equilibrium. There are some limited empirical studies on consumer welfare for quantity changes using the Marshallian surplus. Rucker, Thurman, and Sumner (1980) estimate the inverse demand function for tobacco which is subject to quantity restrictions (quotas) and investigate the welfare effect associated with changes in quotas. Bailey and Liu (1995) estimate an inverse demand for airline services in which air fares are specified as a function of network scale and examine consumer welfare for changes in network scale.

However, the Marshallian surplus is an approximate welfare measure for quantity changes, and there is no formal analysis of exact welfare measures pertinent to the inverse demand system for quantity changes.[16] This is in stark contrast to the literature on price-based welfare measures which provides well-established welfare measures for price change.

[13]According to Hicks, "When we are studying the behavior of the individual consumer, it is natural to regard the former ('price into quantity,' i.e., direct demand) approach as primary, for the consumer is concerned with given prices on the market, and he chooses how much to purchase at a given price. But when we are studying market demand, the demand from the whole group of consumers of the commodity, the latter ('quantity into price,' i.e., inverse demand) approach becomes at least as important. For we then very commonly begin with a given supply, and what we require to know is the price at which that supply can be sold" (Hicks, 1957 and Kim, 1997). Katzner (1970) argues that the inverse demand system may be useful to the economic planner since he may be interested in the prices required to clear the market of planned commodities.

[14]Bronsard and Lise (1984) examine whether a direct or inverse demand system is appropriate in empirical analysis and find that the level of commodity aggregation is important. In particular, their test rejects the exogeneity of prices in three-commodity models, but prices are often considered as exogenous at a more disaggregate level. In addition, see Huang (1988), Barten and Betterdorf (1989), and Eales and Unnevehr (1994) for the rationale of the use of the inverse demand system in food demands.

[15]This is true in a general equilibrium view of the economy where total supply is fixed for the economy, while it is not fixed for individual consumers.

changes (Kim, 1997).

Kim (1997) fundamentally established the theoretical procedure for measurement of welfare changes for the inverse demand system and provided exact welfare measures associated with quantity changes through using compensating and equivalent variation. He explained many circumstances that warrant the use of quantity-based welfare measures, in contrast to the conventional price-based measures. He employed the distance function as a useful tool to develop compensating and equivalent variations for quantity changes, which are contrasted to the Marshallian surplus. He also showed that many results derived for quantity changes are parallel to those of welfare measures for price changes. In view of the increased usage of inverse demand systems and distance functions, welfare measures of quantity changes are of great importance in policy analysis. Moreover, quantity-based welfare measures can also deal with the welfare effects of price changes when there are well-functioning competitive markets.

Beach and Holt (2001) developed the models which were used to estimate inverse demands for finfish landed commercially in the South Atlantic. These models were used to obtain compensating and equivalent variation estimates associated with a 10% reduction in the quantity landed for individual species. Overall, it appears that including quadratic terms in inverse demand specifications offers an improvement in modeling systems in which quantities are taken as exogenous and may prove beneficial in future applications to inverse demand models.

[16]There is a growing literature on quantity-based welfare measures for the restricted or partial demand system in which some subset of commodities are subject to quantity restrictions. Hicks (1956) originally introduced so-called compensating and equivalent surplus measures for this situation. Mäler (1974) shows that Hicksian compensating and equivalent variations defined for price changes can be readily adapted to welfare measures of quantity changes for a partial demand system. Randall and Stoll (1980) demonstrate that with appropriate modifications, Willig's (1976) formulas for bounds on compensating and equivalent variations for price changes carry over to welfare measures of quantity changes. For more, see Bockstael and McConnell (1993), Brslaw and Smith (1995), Lankford (1988), and Haneman's (1991).

Holt and Bishop (2002) developed normalized quadratic inverse demand systems to examine the welfare implications associated with reductions in fish landings. Because state and regional managers of the Great Lakes fishery must balance the competing interests of commercial and recreational fisherman in the face of diminished fish stocks, such an exercise has meaning in a larger policy context. An oft-used policy instrument in this regard is a commercial catch quota (restriction). It is therefore desirable to have a theoretically consistent money-metric measure of the welfare loss to fish consumers associated with the imposition of harvest restrictions. The results showed considerable variations in the magnitudes and relative importance of the compensating and equivalent variation estimates across species and over time.

Park, Thurman, and Easley (2004) used a recently developed synthetic inverse demand system to measure the welfare loss of fish catch restriction. Unlike single equation models, the system-wide approach does not exclude substitution possibilities and includes interactions that are potentially important for understanding fish consumption patterns and price determination. They applied the estimated system by analyzing welfare measures of quantity restrictions: catch restrictions in the grouper and snapper complex off the southeast coast of the U.S. They found the own- and cross-quantity elasticities of inverse demand to be small, implying that prices themselves are good estimates of the average value of restricted catches. Because the quantities, and not the prices, of fish closely related in demand are held constant, these quantity elasticities have the proper general equilibrium interpretation for welfare analysis.

2.4. Econometric Methodology

A large number of econometric studies have focused on the estimation of parameters in singular equation systems (i.e. systems in which the sum of the regressands at each observation is equal to a linear combination of certain regressors). In the context of consumer demand systems, many previous studies have reported results in which the sum of the regressands (typically expenditure on various commodities) at each observation is equal to the value of a regressor (typically total expenditures). Share studies especially constitute one group of empirical studies with singular equation systems, e.g., budget shares, factor shares, and market shares.

In a variety of share studies, the sum of the regressands (shares) at each observation is equal to the unit, regressor. In both the expenditure and share context, singularity of the equation system implies that the contemporaneous disturbance covariance matrix is also singular.

Barten (1969) has shown that when disturbances are serially independent, maximum likelihood (ML) estimates of the parameters in the complete n-equation system can be derived from ML estimation of n-1 equations; moreover, these ML estimates are invariant to the equation deleted.

Aigner (1973) and Parks (1969) specified that the disturbance vector in the singular equation system follows a first order autoregressive process by using Seemingly Unrelated Regression (SUR). The problem with application of SUR estimation technique to the system of equations is that the assumption of no time dependence among the disturbances is clearly untenable for the time series data. Parks (1967) has generalized Zellner's SUR estimation technique to the case where the disturbances exhibit not only contemporaneous correlation, but *n* autocorrelated pattern as well. The technique involves estimating the parameters for the pattern of serial correlation in the separate equations, then transforming the data to eliminate the serial pattern. The transformed equations then satisfy the Zellner's assumptions; and the estimates are obtained in the usual way. In the presence of serially correlated disturbances the Parks estimation technique can be shown to be consistent and asymptotically more efficient than the Zellner's SUR method.

Berndt and Savin (1975) analyzed what singularity implies for the estimation and hypothesis testing of systems of equations with autoregressive disturbances. Although the study restricted the attention to singular equation systems employing shares as regressands, the results carried over to the expenditure specifications. They found in the study that the adding up property of the shares imposes restrictions on the parameters of the autoregressive process. These restrictions generally have not been taken into account in the Parks' study. When these restrictions are not imposed the specification of the model is conditional on the deleted equation. As a result, the system estimates of the parameters and the likelihood ratio (LR) tests are no longer invariant to the equation deleted. Furthermore, singularity of the contemporaneous disturbance covariance matrix raises issues concerning the identification of parameters of the autoregressive process. This identification problem complicates the interpretation of the LR tests. In order to preserve adding up, the autocorrelation coefficients are constrained to be the same in all equations.[17]

[17]Berndt and Savin showed that the adding up property imposes the diagonals of the unknown parameter vector of covariance matrix of error terms to be same. The estimation of misspecified diagonal will provide consistent, but asymptotically inefficient estimates. Even more important, however, the estimate based on the misspecified diagonal will vary with the equation deleted.

Thus, the feasible generalized least square (FGLS) procedure has three steps: (1) estimate the system equations by Zellner's SUR; (2) estimate ρ in the equations with adding up restrictions from the residuals; and (3) use the estimated parameters to transform the model according to the autoregressive FGLS formula and apply SUR to the transformed model.

2.5. Fish Consumption

Katharine (1992) detected a variety of factors affecting on aquaculture products. The study indicated that changes in lifestyle in the U.S., including an increased preoccupation with healthy behaviour leading to a shift away from red meat to other sources of protein and increased away-from-home eating, may explain the recent growth in seafood consumption. Shifts in fish consumption patterns may also be explained by technological improvements in preparing and marketing of processed fishery products, including convenience products such as breaded shrimp and seafood dinners.

As more and more women enter the work force, increase in opportunity cost of the household meal preparer's time made processed fishery products popular. Improvements in distribution and merchandising techniques by seafood producers and retailers of seafood products, ensure that quality standards meet consumers' expectations. At the same time, national and state-supported consumer education campaigns, attempting to raise the average American's knowledge about the advantages of eating a broader range of seafood products may have had a significant impact on seafood demand.

Adams et. al. (1987) assessed causal relationships by using Haugh-Pierce, Sims, and Granger methods. Price models at three different market levels were estimated. Economic factors analyzed were income, prices of competing products, landings and imports of raw headless shrimp, total retail supply, beginning stocks, and marketing costs.

Monthly prices generally exhibited unidirectional causality from ex-vessel to retail price. Quarterly prices were determined interdependently among market levels. Price responses between market levels were found to be symmetric with beginning stocks, landings, and imports of own-size shrimp the most important determinants of prices. The study recognized that several factors are suspected to have contributed to price volatility, such as limited domestic shrimp supplies, increasing dependency on tariff-free imports of wild catch and increasing amounts of maricultured product, disproportionate increases in costs of production (i.e., fuel, financing, and marine insurance), and fluctuation domestic economic conditions.

Carel et. al. (1996) evaluated the effects of increased exports from NAFTA member countries on the U.S. domestic catfish industry. The study showed that the quantity of catfish imported will fall if the domestic price of catfish falls relative to the import price. Past imports have no effect on present imports. The income elasticity was negative indicating that imported catfish may be an inferior good. This study also showed that doubling present levels of imports from NAFTA member countries is not a threat to the U.S. catfish industry.

Keefe (2001) provided an in-depth analysis of shrimp price flexibility and the impact of decreases in quantity supplied of shrimp on world price. Seemingly Unrelated Regression is utilized to determine price flexibility of shrimp and changes in quantity supplied on world shrimp price. The key objective of this paper is to use Huang's direct procedure and Eales' indirect technique for calculating price flexibilities to evaluate the effects of a reduction in quantity supplied from shrimp aquaculture sources on world price. Estimated price flexibility for the quantity supplied of aquaculture shrimp was -0.32. The results indicate that if world supply should plummet, due to deteriorating environmental conditions, such as disease or pollution, world shrimp price would increase substantially.

Jolly (1998) forecasted catfish industry prices by using linear and nonlinear methods. Autoregressive conditional heteroscedastic (ARCH) models and the generalized autoregressive conditional heteroscedastic (GARCH) are employed with ordinary least squares (OLS), unconditional least squares (ULS), and maximum likelihood (ML) models to forecast prices. These forecasts are compared to traditional OLS model forecasts. All models had comparable statistics (RSME, MAE, R2), but ULS and the ML produced forecasts with less deviation from the observed values. The nonlinear models showed an improvement in price forecasts over the ordinary least squares (OLS) medels for prices of whole and frozen catfish.

Schmitz and Seale (2004) analyzed the effect that offset payments under the Continued Dumping and Subsidy Offset Act (CDSOA also known as the "Byrd Amendment") have on tariff levels that are lobbied for by U.S. producer groups. The study derived the optimum antidumping tariff that would maximize the welfare of producers receiving CDSOA offset payments. They compared and contrasted this newly derived "optimal antidumping tariff" (that maximizes the sum of producer surplus and tariff revenue) with the optimal revenue tariff (that maximizes tariff revenue alone) and the optimal welfare tariff (that maximizes the sum of consumer surplus, producer surplus, and tariff revenue). Prior to the CDSOA, U.S. producers would always lobby for prohibitive tariffs that maximize producer surplus. However, under the CDSOA, producers will, in most cases, lobby for a tariff that is not prohibitive but is still higher than the optimal revenue or optimal welfare tariffs.

CHAPTER 3

ECONOMIC FRAMEWORK

Since inverse demand systems provide the theoretical basis for empirical applications related to analysis of quantity effects for price adjustable products, the studies of inverse demand systems have been focused on by many economists. For example, due to biological lag of the production process and perishability of fish, price should be adjusted based on quantity supplied to clear the market, for which the inverse demand system provides theoretical basis.

Gossen, who earlier introduced the concept of diminishing marginal utility, described a consumer's equilibrium as the proportionality between the vector of prices and that of the consumer's marginal utilities. This concept became commonly known later as Gossen's Second Law.[18] The consumer's marginal utilities are functions of the quantities of commodities. This function can be derived from maximizing the utility condition of given income as follows:

(3.1) $\underset{q}{Max}\, U(q)$ subject to $p'q = 1$.

Under the regularity condition, this equilibrium implies a relation between price variations and quantity variations.[19]

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[18]Gossen's Second Law was his most original contribution and presaged the Marginalist Revolution of 1871-74. For example, Walras (1874) stated as that "In fact, the whole world may be looked upon as a vast general market made up of diverse special markets where social wealth is bought and sold. Our task then is to discover the law to which these purchases and sales tend to confirm automatically. To this end, we shall suppose that the market is perfectly competitive, just as in pure mechanics we suppose to start with, that machines are perfectly frictionless." Moor (1914) followed this same train of thought when he made the statement: "In the closing quarter of the last century, great hopes were entertained by economists with regard to the capacity of economics to be made an "exact science". According to the view of the foremost theorists, the development of the doctrine of utility and value had laid the foundation of scientific economics in exact concepts, and it would soon be possible to erect upon this new foundation a firm structure of interrelated parts which, in definiteness and cogency, would be suggestive of the severe beauty of the mathematico-physical sciences. But this expectation has not been realized."

If one writes this relation with the quantities expressed as a function of the prices, then one has a direct consumer demand system, $q = h(p)$. From a theoretical point of view one could just as well express the prices as a function of the quantity. One then has what is known as an inverse demand system, $p = b(q)$.

From an empirical point of view, however, direct and inverse demand systems are not equivalent as has been shown previously in Chapter II. To avoid statistical inconsistencies, the right-hand side variables in such systems of random decision rules should be the ones which are not controlled by the decision maker, i.e., $E(p \cdot e) = 0$ in equations (2.3) and (2.4) for direct demand systems and $E(q \cdot \varepsilon) = 0$ in equations (2.1) and (2.2) for inverse demand systems, respectively. If the consumer is a price taker and a quantity adjuster for most of the products and services usually purchased, the direct demand system is desirable for the case. However, due to biological lag in the production process for certain goods like fresh vegetables or fish, supply is very inelastic in the short run and producers are virtually price takers. These price taking producers and price taking consumers are linked by traders who select a price which they expect will clear the market. This means, in practice, that at auction, wholesale traders offer prices for the fixed quantities which, after being augmented with a suitable margin, are sufficiently low enough to induce consumers to buy the available quantities. In that case, traders set the prices as a function of the quantities so that the inverse demand system can be obtained.

[19]The regularity condition assumes that the direct utility function, $u = U(q)$, is to be twice-continuously differentiable, increasing, and quasi-concave in q, a vector of commodities.

There has been in recent years an increasing interest in the systems of inverse demand functions in which normalized prices are functions of normalized quantities demanded.[20] These systems are particularly useful in markets for agricultural and natural resource commodities like fish and vegetables. Such inverse demand systems have been developed according to two different approaches. The first one utilizes the Rotterdam methodology, which is a direct approximation of the conceptual inverse demand relationships without imposing the rigid structure that is implied by utility maximization – see Barten and Bettendorf (1989), Eales, Durhan, and Wessells (1997), Park, Thurman, and Easley (2004), and Matsuda (2005). Even though the Rotterdam method is difficult to incorporate into the demand systems without having an idea about the structure of preferences, the Rotterdam method can obtain the inverse demand systems which explain well the quantity effect on price in terms of the substitution effect and the scale effect.

An alternative method to the Rotterdam method is based on a dual representation of preferences, which, in turn, is based on a specified functional form of the direct utility or distance function – see Kim (1997), Beach and Holt (2001), Holt and Bishop (2002), and Wong and McLaren (2005).

[20] Normalized price of commodity *i* is obtained as follows:

$p_i = \frac{p_i^*}{m}$, where p_i^* is nominal price of commodity *i* and $m = \sum_{i=1}^{n} p_i q_i^*$.

Normalized quantity is obtained as follows:

$q_i = \frac{q_i^*}{q_{i,mean}}$, where q_i^* is quantity of commodity *i* and $q_{i,mean}$ is mean of quantity of commodity *i*.

Since the Rotterdam method starts initially from the relationship between price and quantity to derive the targeted inverse demand system, this methodology does not need the specific functional form of consumer preference.[21] The Rotterdam method is initially constructed by Barten and Bettendorf (1989) and subsequently by Brown, Lee, and Seal (1995), Park (1996), and Eales, Durhan, and Wessels (1997). With assumptions of weak separability of the total commodity bundle into eight fishery products and collective consumer behavior as a rational representative consumer, Barten and Bettendorf (1989) initiated the four different types of inverse demand systems, Differential Inverse Rotterdam Demand System (DIRDS), Differential Inverse Almost Ideal Demand System (DIAIDS), Differential Inverse Central Bureau of Statistics (DICBS), and Differential Inverse National Bureau of Research (DINBR). Since the appearance of the inverse demand systems, Brown, Lee, and Seale (1995) have developed the inverse demand systems into the generalized inverse demand system, nesting these four inverse demand systems. Since then, economists have used the generalized inverse demand systems for empirical analysis. For example, Eales, Durham, and Wessells (1997) developed generalized inverse demand systems of Japanese demand for fish from the inverse demand systems. Park, Thurman, and Easley (2004) modeled inverse synthetic demand systems for empirical welfare measurement in Gulf and South Atlantic fisheries.

[21]Wong and McLaren (2005) indicated the weakness of the Rotterdam methodology as follows: “It may be inconvenient to incorporate prior idea about the structure of preferences, which is always required when working with highly disaggregated inverse demand systems, noting that such information (which must be matched to the aggregation level at which estimation is to proceed) often takes the form of statements about relative substitutability among items within different commodity groups."

An alternative methodology to the Rotterdam method based on a dual representation of preference is typified by Kim (1997), who theoretically derived the targeted inverse demand system from the distance function, which is derived from a given direct utility function. This inverse demand system was also used for welfare measurement in quantity space.

In this chapter, this study will discuss 1) the two different economic approaches to derive inverse demand systems, 2) consumer's economic welfare measurement in quantity space, and 3) producer welfare measurement using price and cost flexibilities.

3.1. Inverse Demand System

3.1.1. Rotterdam Methodology

From here the study will use the same quantity and price variables defined in equations (1.6) and (1.8). According to basic demand theory, the market demand can be defined by a system of Marshallian demand as follows:

(3.2) $q = f(p^*, m)$

where q is the n-vector of normalized quantity, p^* is the n-vector of corresponding nominal price, and m is total expenditure on the sub-bundle of commodities, $m = p^{*\prime}q$. This specification is more convenient to derive the inverse demand systems whenever we can easily recognize what type of functional form of regular demand in the light of relationship between price and quantity than that of the distance function methodology, which requires the specific form of the utility or distance function rather than that of the demand function. In view of homogeneity of degree zero in m and p^*, the equation (3.2) can be normalized without losing any of the following demand function properties:

(3.3) $q = h(p)$

where $p = \frac{p^*}{m}$ is the normalized price vector. Here, p_i would be interpreted as the fraction of total expenditure paid for one unit of good *i*. It should be noted that the normalized price, *p,* is the same for the producer, wholesale, and retail prices if the seller's margin is proportional to the price. The traders will select p such that the given quantities q are bought. The prices they offer to the fish producers result in the inverse demand system from inverting equation (3.3) as follows:

(3.4) $p = h^{-1}(q) = b(q)$

which does not lose any property held by equations (3.2) and (3.3). Now, in order to derive more flexible inverse demand systems, we should carefully review the properties of inverse demand systems and an adequate parameterization. Recalling that the properties of the inverse demand system depends on the properties of equations (3.2) and (3.3), the properties of equation (3.4) can be deduced directly from the following conditions:

(3.5) $u_q = \lambda p, \quad p'q = 1$

where $u_q = dU(q)/dq$ is the vector of marginal utilities and $\lambda = q'u_q$ is a Lagrange multiplier. $u_q = \lambda p$ describes consumer equilibrium as the proportionality between the vector of prices and that of the consumer's marginal utilities indicated by Gossen. Now, these systems for p should be solved to define the inverse demand systems as a function of quantities. Therefore, p is expressed as follows:

(3.6) $p = (1/\lambda)u_q = (1/q'u_q)u_q$

which is another mathematical expression for (3.4). However, equation (3.6) gives a clue on how to derive more useful information regarding consumer preference and price behavior related to a change in quantity. In order to study the relation between quantity, price, and utility in more detail, it should be considered that a small change in q results in a shift in p, noting that a change in marginal utility can be calculated by using the Hessian matrix of the utility function because $du_q = u_{qq}dq$ where $u_{qq} = [d^2U(q)/dqdq]$ is the Hessian matrix of the utility function. This relation would be studied by total differentiation of equation (3.6). The total differential equation is as follows:

$$(3.7) \qquad dp = -(1/q^{2}u_q)u_q dq + (1/q'u_q)du_q - (1/q'u_q^2)u_q du_q$$

$$= (1/q'u_q)[-pu'_q dq + (I - pq')du_q]$$

$$= -pp'dq + (I - pq')(1/q'u_q)u_{qq}dq$$

$$= -pp'dq + (I - pq')Vdq$$

where $V = (1/q'u_q)u_{qq}$ is a symmetric matrix because the Hessian matrix, u_{qq}, is symmetry. Equation (3.7) can be rearranged to be more efficient form as follows:

$$(3.8) \qquad dp = -[p - (I - pq')Vq]p'dq + (I - pq')V(I - qp')dq$$

$$= gp'dq + Gdq$$

where $g = -[p - (I - pq')Vq]$ and $G = (I - pq')V(I - qp')$.

With equation (3.8), we can describe the change in p caused by a change in q. The change in p would be interpreted by the effect of two shifts in q. The first one, $gp'dq$, can be described as a scale effect, which is equivalent to the second part of right hand side of equation (3.79) in the distance function methodology. Since a proportionate increase in q means $dq = kq$, with k being a positive scalar, it follows from equation (3.5) then that $p'dq = kp'q = k$. Simultaneously, we also know $Gq = 0$ because $(I - pq') = 0$. As a result, the second effect in equation (3.8) will be zero,

$Gdq = kGq = 0$, for a proportionate increase in q. Therefore, the change in scale can only be explained by $gp'dq$ whenever a proportionate increase in q occurs. The change in scale is monotonically related to a change in utility. Let du be such a change. One has, using equation (3.5), $du = u_q^{'} dq = \lambda p' dq = \lambda k p' q = \lambda k$ with $\lambda > 0$. This means that Gdq is the (utility or real income) compensated for substitution effect of quantity changes, which is equivalent to the first part of the right hand side of equation (3.79) in distance function methodology. Also, G is the counterpart of the Slutsky matrix for regular demand systems and known as the Antonelli (substitution) matrix – Antonelli (1886), Salvas-Bronsard et al. (1977), Laitinen and Theil (1979), Anderson (1980), and Barten and Bettendorf (1989). Gdp represents the move along an indifference surface, while $gp' dq$ is the move from one difference surface to another.

Substitution effect, Gdq, and scale effect, $gp' dq$, can be shown under different relationships between commodities. Figure 3.1 shows the substitution effect and scale effect for q-complements of q_j and q_i, in which an increase in q_j increases p_i. An increase in p_i causes the demand of q_i to decrease by dq_i shown in Figure 3.1. In contrast, Figure 3.2 shows the substitution effect and scale effect for q-substitutes of q_j and q_i, in which an increase in q_j decreases p_i. A decrease in p_i causes the demand of q_i to increase by dq_i shown in Figure 3.2. Figure 3.3 shows substitution effect and scale effect for the case of an inferior good of q_j, in which substitution effect is positive but scale effect is negative so that the total effect is the substitution effect minus the scale effect.

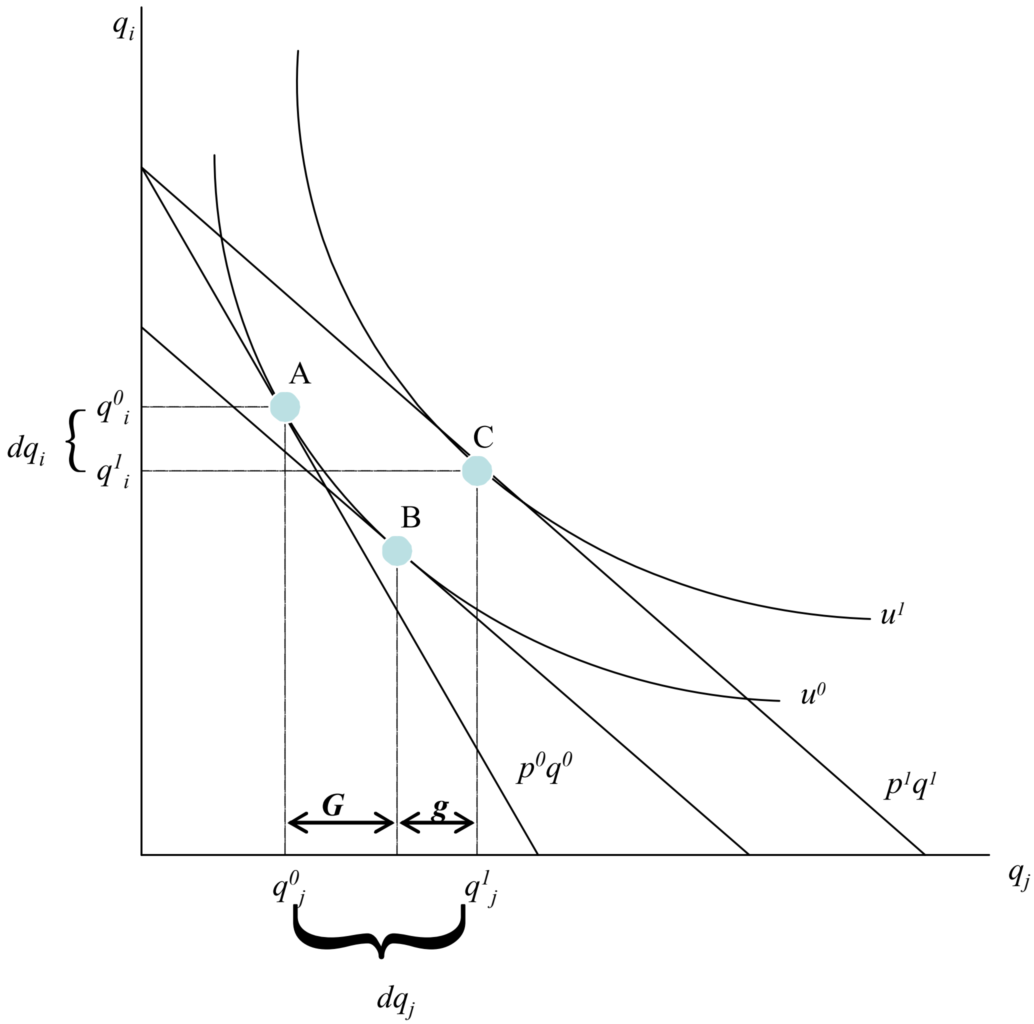

Figure 3.1. Substitution Effect and Scale Effect for *q*-Complements.

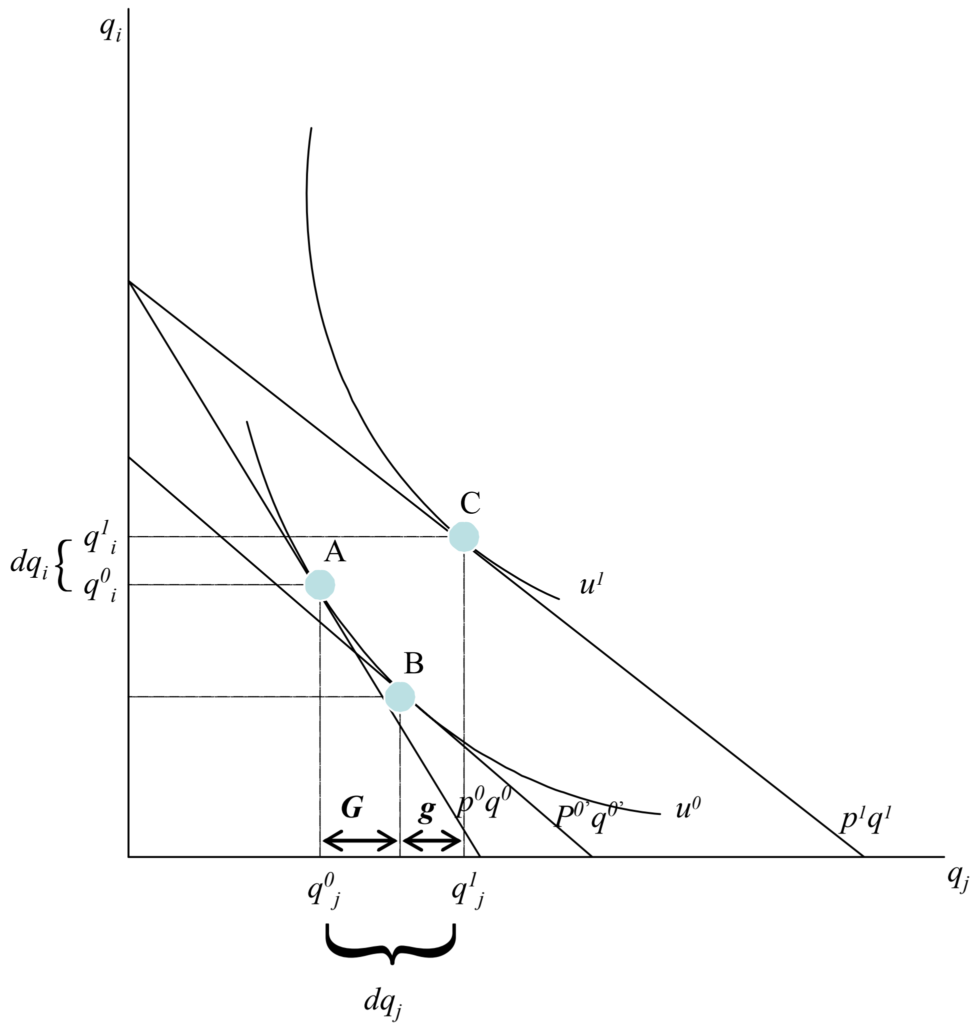

Figure 3.2. Substitution Effect and Scale Effect for q-Substitutes.

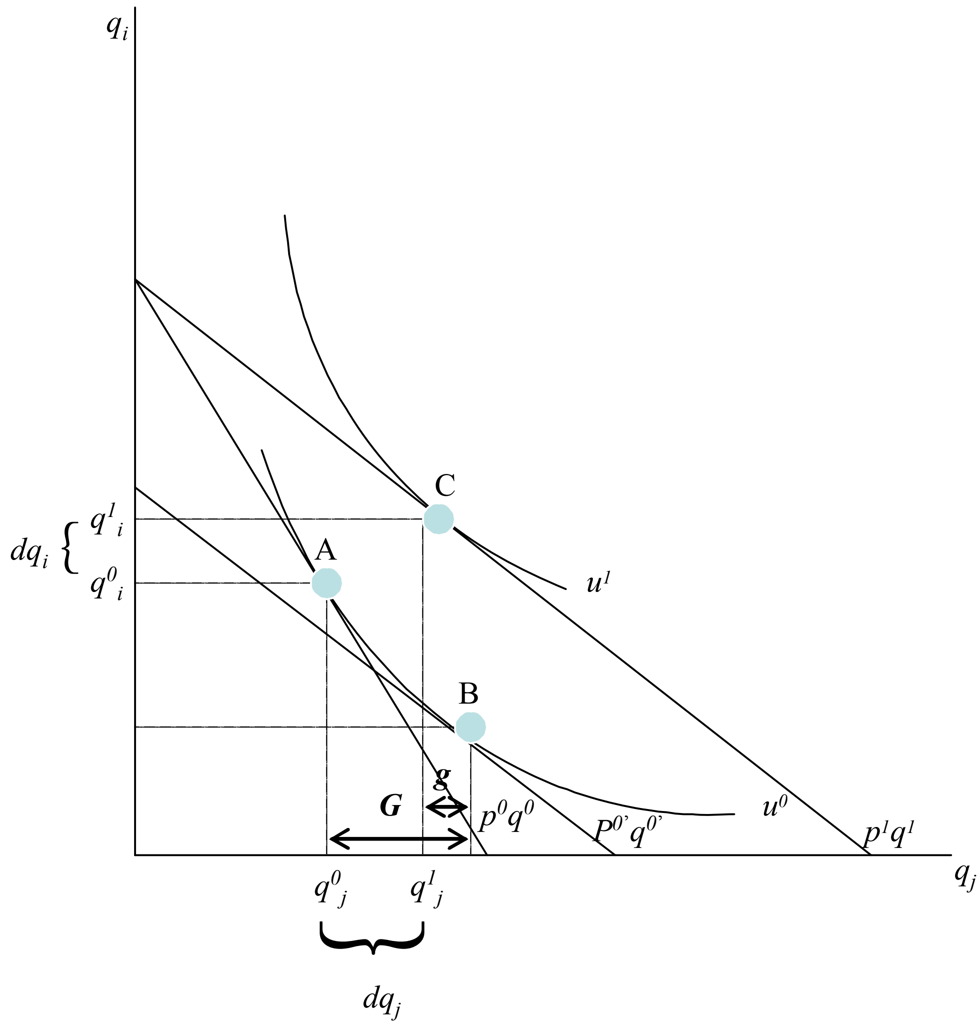

Figure 3.3. Substitution Effect and Scale Effect for Inferior Good of q_j

$p'dq$ in equation (3.8) can be manipulated to have the form of scale measure as follows:

(3.9) $$p'dq = \sum_i p_i dq_i = \sum_i p_i q_i d\ln q_i = \sum_i w_i d\ln q_i = d\ln Q$$

where $w_i = p_i q_i = p_i^* q_i / m$ is the share of expenditure on good i in total expenditure. We may thus consider $p'dq$ also as the change in the *Divisia quantity index*. Now, equation (3.8) would be modified by the *Divisia quantity index* as follows:

(3.10) $$dp = gd\ln Q + Gdq$$

A further property follows from the differential form of $p'q = 1$, namely $p'dq + q'dp = 0$, yielding $q'dp = -p'dq = -d\ln Q$.

From this property and from the definitions of g and G we can derive the *adding-up* conditions as follows:

(3.11) $$\begin{aligned} & p'dq + q'dp \\ &= p'dq + q'(gp'dq + Gdq) \\ &= p'dq + q'g(p'dq) + qGdq \\ &= p'dq(1 + q'g) + qGdq \\ &= 0 \end{aligned}$$

As a result, the adding up conditions will be defined by $q'g = -1$ and $q'G = 0$. The property $Gq = 0$ can be named *homogeneity* condition because it ensures that a proportionate increase in q is neutralized as far as this substitution effect is concerned. The matrix G is obviously symmetric. It is moreover negative semi-definite of rank one less than its order. This last property follows from the strictly quasi-concavity condition of the underlying utility function, which implies that $x'u_{qq}x < 0$ for all $x \neq 0$ such that

$u_q^{'} x = 0$ - see Barten and Böhm (1982). This condition is equivalent to $x'Vx < 0$ for all $x \neq 0$ such that $p'x = 0$. Then, we can write for $y = (I - qp')z$ as follows:

(3.12) $$zGz = z'(I - pq')V(I - qp')z = y'Vy$$

This equation will be zero if and only if z is proportional to q, because then $y = 0$. Otherwise it is negative, since $p'y = p'(I - qp')z = 0$. One consequence of this property is the negativity of the diagonal elements of Antonelli matrix G.

The adding-up $(q'g = -1)$ and homogeneity $(Gq = 0)$ conditions for the vector g and the Antonelli matrix G involve the vector of the variable quantities. It should be noted that "Using the g and G as constants is then not very attractive, at least if one wants to use these conditions as constraints on the parameter estimation" as Barten and Bettendorf indicated.[22]

In differential inverse demand systems, the individual equation of equation (3.10), $dp_i = g_i d\ln Q + \sum_j g_{ij} dq_j$, would be multiplied through by q_i to obtain the following equation:

(3.13) $$q_i dp_i = h_i d\ln Q + \sum_j h_{ij} dq_j / q_j$$

with $h_i = q_i g_i$, and $h_{ij} = q_i g_{ij} q_j$ as constants. For the variable on the left-hand side we have $q_i dp_i = q_i p_i \left(\frac{dp_i}{p_i} \right) = q_i p_i d\ln p_i = w_i d\ln p_i$. Equation (3.13) can then be written as follows:

(3.14) $$w_i d\ln p_i = h_i d\ln Q + \sum_j h_{ij} d\ln q_j$$

[22] A similar situation occurs for a regular demand system in differentials. Theil (1965) proposed to multiply the ith regular demand equation through by p_i to arrive, after some rearrangements, at a choice of constants which satisfy the usual conditions in a natural way. The resulting system is known as the Rotterdam system.

Equation (3.14) is the inverse analogue of the regular Rotterdam demand system. It is named the differential inverse Rotterdam demand system (DIRDS).

In equation (3.14), we can define adding up, homogeneity, and symmetry of h_i and h_{ij} with negativity condition as follows:

(3.15) $\sum_i h_i = -1$ (Adding up)

(3.16) $\sum_i h_{ij} = 0$ (Adding up)

(3.17) $\sum_j h_{ij} = 0$ (Homogeneity)

(3.18) $h_{ij} = h_{ji}$ (Symmetry)

(3.19) $\sum_i \sum_j x_i h_{ij} x_i < 0 \quad \forall x \neq \theta_l ,\ \theta \in \Re$ (Negativity)

Actually, the differential inverse demand system of Laitinen and Theil (1979) is somewhat different.[23] It can be obtained by adding to both sides of equation (3.14) $w_i d \ln Q$ and treating the $c_i = h_i + w_i$ as constants. The variable on the left-hand side is then modified as follows:

(3.20)
$$\begin{aligned} & w_i (d \ln p_i + d \ln Q) \\ &= w_i (d \ln p^*{}_i - d \ln m + d \ln Q) \\ &= w_i (d \ln p^*{}_i - d \ln P) \\ &= w_i d \ln (p^*{}_i / P) \end{aligned}$$

with $d \ln m - d \ln Q = d \ln m - \sum_i w_i d \ln q_i = \sum_i w_i d \ln p_i^* = d \ln P$, *Divisia price index*. We then have another differential inverse demand system called the differential inverse CBS demand system (DICBS) as follows:

[23]Laitinen and Theil (1979) showed that the inverse demand models can be formulated by means of the Antonelli matrix or the reciprocal Slutsky matrix. The two approaches differ with respect to the price deflator and the role of the Divisa quantity index.

$$w_i d\ln(p^*_i / P) = c_i d\ln Q + \sum_j h_{ij} d\ln q_j \qquad i, j = 1,...,n \tag{3.21}$$

In equation (3.21), the dependent variable now involves the relative price of commodity i rather than the normalized prices. Equation (3.21) relates to equation (3.14) as the Central Bureau of Statistics regular demand system of Keller and Van Driel (1985) does to the regular Rotterdam system.[24] In equation (3.21), adding up, homogeneity, and symmetry of c_i and h_{ij} can be defined similarly with in DIRDS as follows:

(3.22) $\sum_i c_i = \sum_i (h_i + w_i) = 0$ (Adding up)

(3.23) $\sum_i h_{ij} = 0$ (Adding up)

(3.24) $\sum_j h_{ij} = 0$ (Homogeneity)

(3.25) $h_{ij} = h_{ji}$ (Symmetry)

Another variant is possible by adding $w_i(d\ln q_i - d\ln Q)$ to both sides of equation (3.21). On the left-hand side we then have, in view of equation (3.20), $w_i(d\ln p^*_i + d\ln q_i - d\ln P - d\ln Q) = w_i d\ln w_i = dw_i$.

Consequently, we can get another type of inverse demand systems as follows:

$$dw_i = c_i d\ln Q + \sum_j c_{ij} d\ln q_j \tag{3.26}$$

with the $c_{ij} = h_{ij} + w_i\delta_{ij} - w_i w_j$ (where δ_{ij} is a Kronecker delta) now treated as constants. This is the differential inverse almost ideal demand system (DIAIDS), which is the

[24]Keller and Driel (1985) derived the CBS model, which combines the preferred Engel curve with the simplicity of Slutsky matrix, including the ease of implementing concavity and other restrictions. The model is based on the PIGLOG Engel curve and constant Slutsky coefficients.

inverse analogue of the linear version of the regular differential Almost Ideal Demand System (AIDS) of Deaton and Mullbauer (1980).[25]

In equation (3.26), the adding up, homogeneity, and symmetry conditions of c_i and c_{ij} can be defined as follows:

(3.27) $\sum_i c_i = \sum_i (h_i + w_i) = 0$ (Adding up)

(3.28) $\sum_i c_{ij} = \sum_i (h_{ij} + w_i \delta_{ij} - w_i w_j) = 0$ (Adding up)

(3.29) $\sum_j c_{ij} = \sum_j (h_{ij} + w_i \delta_{ij} - w_i w_j) = 0$ (Homogeneity)

(3.30) $c_{ij} = c_{ji}$, or $(h_{ij} + w_i \delta_{ij} - w_i w_j) = (h_{ji} + w_j \delta_{ji} - w_j w_i)$ (Symmetry)

Another variant is possible by subtracting $w_i d \ln Q$ from both sides of equation (3.26), which will lead to another type of differential inverse demand system which is as follows:

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

This is the differential inverse NBR demand system (DINBR), which is the inverse analogue of the linear version of the regular differential NBR demand system of Neves (1994).[26] In equation (3.31), the adding up, homogeneity, and symmetry conditions of h_i and c_{ij} can be defined as follows:

[25]Deaton and Mullbauer (1980) introduced the AIDS model, in which the budget shares of the various commodities are linearly related to the logarithm of real total expenditure and the logarithms of relative prices. The model is shown to possess most of the properties usually thought desirable in conventional demand analysis, and to do so in a way not matched by any single competing system.

[26]Neves (1994) showed that the Rotterdam, AIDS, CBS, and NBR models constitute a class of differential regular demand system.

(3.32) $\sum_i h_i = -1$ (Adding up)

(3.33) $\sum_i c_{ij} = \sum_i (h_{ij} + w_i \delta_{ij} - w_i w_j) = 0$ (Adding up)

(3.34) $\sum_j c_{ij} = \sum_j (h_{ij} + w_i \delta_{ij} - w_i w_j) = 0$ (Homogeneity)

(3.35) $c_{ij} = c_{ji}$, or $(h_{ij} + w_i \delta_{ij} - w_i w_j) = (h_{ji} + w_j \delta_{ji} - w_j w_i)$ (Symmetry)

There is not a parallel to the negativity condition in this case, however. Clearly, DICBS and DINBR are crosses between DIRDS and DIAIDS (Barten and Battendorf, 1989). With these four inverse demand systems, economists have constructed a more flexible inverse demand system wherein others are nested. The development follows, in the inverse demand context, a suggestion by Barten (1993). The extension of Bartern's method to inverse demand systems was recorded independently by Brown, Lee, and Seale (1995) and by Park (1996). An application can be found in Eales, Durham, and Wessells (1997). Barten's motivation for combining models is that, empirically, a particular coefficient in one model may perform better than its counterpart in other models. This motivates interest in combinations of models that allow the data to choose the forms for specific effects.

As just seen in equation (3.14), (3.21), (3.26), and (3.31), the left-hand sides in the four differential inverse demand systems are different, while the right-hand sides are linear in the same variables. This allows the four systems to be written as follows:

(3.36) DIRDS: $y_i^R = X'\Pi_i^R + \varepsilon_i^R$

DICBS: $y_i^C = X'\Pi_i^C + \varepsilon_i^C$

DIAIDS: $y_i^A = X'\Pi_i^A + \varepsilon_i^A$

DINBR: $y_i^N = X'\Pi_i^N + \varepsilon_i^N$

A linear combination of the four systems can be written as follows:

(3.37) $a_R y_i^R + a_C y_i^C + a_A y_i^A + a_N y_i^N = X'\Pi_i + \varepsilon_i$

where $\Pi = a_R \Pi_i^R + a_C \Pi_i^C + a_A \Pi_i^A + a_N \Pi_i^N$ and ε_i is a composite error. Normalizing the sum of the a_k weights to equal one yields:

(3.38) $y_i^R = X'\Pi_i + a_C (y_i^R - y_i^C) + a_A (y_i^R - y_i^A) + a_N (y_i^R - y_i^N)$

Finally, note that the right-hand side differences in equation (3.25) are (i) exogenous and (ii) collinear, which can be seen as follows:

$$\begin{aligned}(3.39)\quad & y_i^C - y_i^R = w_i d\ln(p_i^* / P) - w_i d\ln(p_i^* / M) = w_i d\ln Q \\ & y_i^A - y_i^C = w_i d\ln(p_i^* q_i / m) - w_i d\ln(p_i^* / P) = w_i d\ln(q_i / Q) \\ & y_i^N - y_i^A = dw_i - w_i d\ln(Q) - dw_i = -w_i d\ln Q\end{aligned}$$

Equation (3.39) allows the hybrid system to be written in estimation form as follows:

(3.40) $y_i^R = X'\pi_i + \theta_1 (y_i^R - y_i^C) + \theta_2 (y_i^R - y_i^N)$

where $\theta_1 = a_C + a_A$ and $\theta_2 = a_N + a_A$. In terms of the underlying variables:

$$\begin{aligned}(3.41)\quad w_i d\ln p_i &= \sum_j \pi_{ij} d\ln q_j + \pi_i d\ln Q - \theta_1 w_i d\ln Q - \theta_2 w_i d\ln(q_i / Q) \\ &= \sum_j (\pi_{ij} - \theta_2 w_i \delta_{ij} + \theta_2 w_i w_j) d\ln q_j + (\pi_i - \theta_1 w_i) d\ln Q\end{aligned}$$

where $\pi_{ij} \equiv (1-\theta_2) h_{ij} + \theta_2 c_{ij}$ and $\pi_i \equiv (1-\theta_1) h_i + \theta_1 c_i$.

This basic nesting system of equations will be called the Generalized Inverse Demand System (GIDS). The θ_1 and θ_2 parameters can be thought of as indicators of DIAIDS scale and substitution effects. If $\theta_1 = \theta_2 = 0$, the DIAIDS effects are zero and the GIDS reduces to the DIRDS. If $\theta_1 = \theta_2 = 1$, both DIAIDS effects are present and the system becomes DIAIDS. If $\theta_1 = 1$ and $\theta_2 = 0$, the GIDS becomes the hybrid DICBS. If $\theta_1 = 0$ and $\theta_2 = 1$, the GIDS becomes the complementary hybrid, the DINBR.

There are two sets of restrictions on the parameters of equation (3.41). As in DIRDS, DIAIDS, DICBS, and DINBR, the restrictions of adding up, homogeneity, and symmetry can be imposed for equation (3.41) as follows:

(3.42) $\sum_i (\pi_{ij} - \theta_1 w_i) = -1$ (Adding up)

(3.43) $\sum_i (\pi_{ij} - \theta_2 w_i \delta_{ij} + \theta_2 w_i w_j) = \sum_i \pi_{ij} = 0$ (Adding up)

(3.44) $\sum_j (\pi_{ij} - \theta_2 w_i \delta_{ij} + \theta_2 w_i w_j) = \sum_j \pi_{ij} = 0$ (Homogeneity)

(3.45) $\pi_{ij} = \pi_{ji}$ (Symmetry)

In the Rotterdam methodology, monotonicity and concavity cannot be easily imposed. However, these restrictions can be easily reflected in the inverse demand system whenever we can define the distance function as linear homogeneity and concavity (see the distance function methodology). The scale and price flexibilities can be derived easily from equation (3.41). The scale flexibility can be described as follows:

(3.46) $f_i = \pi_i / w_i - \theta_1$ (Scale flexibility)

The price flexibilities can be described as follows:

(3.47) $f_{ij}^* = \pi_{ij} / w_i + \theta_2 w_j$ (Compensated cross-price flexibility)

(3.48) $f_{ii}^* = \pi_{ii} / w_i - \theta_2 + \theta_2 w_i$ (Compensated own-price flexibility)

(3.49) $f_{ij} = f_{ij}^* + w_j f_i$ (Uncompensated price flexibility)

In equation (3.46) to (3.48), if $\theta_1 = \theta_2 = 0$, the DIRDS's scale and price flexibilities are turned on as follows:

(3.50) $f_i = h_i / w_i$ (DIRDS's scale flexibility)

The DIRDS's price flexibilities can be described as follows:

(3.51) $f_{ij}^{*} = h_{ij} / w_i$ (DIRDS's compensated cross-price flexibility)

(3.52) $f_{ii}^{*} = h_{ii} / w_i$ (DIRDS's compensated own-price flexibility)

(3.53) $f_{ij} = f_{ij}^{*} + w_j f_i$ (DIRDS's uncompensated price flexibility)

If $\theta_1 = \theta_2 = 1$, the DIAIDS's scale and price flexibilities are turned on as follows:

(3.54) $f_i = c_i / w_i - 1$ (DIAIDS's scale flexibility)

The DIAIDS's price flexibilities can be described as follows:

(3.55) $f_{ij}^{*} = c_{ij} / w_i + w_j$ (DIAIDS's compensated cross-price flexibility)

(3.56) $f_{ii}^{*} = c_{ii} / w_i - 1 + w_i$ (DIAIDS's compensated own-price flexibility)

(3.57) $f_{ij} = f_{ij}^{*} + w_j f_i$ (DIAIDS's uncompensated price flexibility)

If $\theta_1 = 1$ and $\theta_2 = 0$, the hybrid DICBS's scale and price flexibilities are turned on as follows:

(3.58) $f_i = c_i / w_i - 1$ (DICBS's scale flexibility)

The DICBS's price flexibilities can be described as follows:

(3.59) $f_{ij}^{*} = h_{ij} / w_i$ (DICBS's compensated cross-price flexibility)

(3.60) $f_{ii}^{*} = h_{ii} / w_i$ (DICBS's compensated own-price flexibility)

(3.61) $f_{ij} = f_{ij}^{*} + w_j f_i$ (DICBS's uncompensated price flexibility)

If $\theta_1 = 0$ and $\theta_2 = 1$, the DINBR are turned on as follows:

(3.62) $f_i = h_i / w_i$ (DINBR's scale flexibility)

The DINBR's price flexibilities can be described as follows:

(3.63) $f_{ij}^{*} = c_{ij} / w_i + w_j$ (DINBR's compensated cross-price flexibility)

(3.64) $f_{ii}^{*} = c_{ii} / w_i - 1 + w_i$ (DINBR's compensated own-price flexibility)

(3.65) $f_{ij} = f_{ij}^{*} + w_j f_i$ (DINBR's uncompensated price flexibility)

In order to confirm the availability for estimation of price flexibility and scale flexibility for the nine types of fish used in this study, this study will not only utilize the four individual inverse demand systems but will also employ the generalized inverse demand system developed from the four inverse demand systems.

3.1.2. Distance Function Methodology

Even though the Rotterdam methodology is a convenient tool to generate a system of inverse demand equations, the curvature conditions implied by economic theory should be maintained to generate a theoretically consistent inverse demand system. In view of such restrictions, it is useful to specify a distance function with a given level of utility, u. Due to the relative ease with which curvature can be related to the properties of the Antonelli matrix, the distance function is a convenient vehicle for generating inverse demand systems incorporating structural features required for most welfare analysis applications. Furthermore, since concavity (the curvature property of the distance function) and monotonicity are preserved under addition and the nesting of increasing concave functions, a straightforward way of generating wider classes of regular distance functions is readily available (Wong and McLaren, 2005).

According to Shephard's lemma, duality theory indicates that the compensated inverse demand systems can be derived from the distance function via simple differentiation. While these functions are conditioned on an unobservable variable (utility), in most cases they do not have an explicit closed form representation as the uncompensated inverse demand functions, that is, in terms of the observable variables such as quantities.[27] As McLaren, Rossiter, and Powell (2000) showed in the context of the expenditure function, the unobservability of utility need not hinder estimation.[28] A simple one-dimensional numerical inversion allows estimation of the parameters of a particular distance function via the parameters of the implied inverse uncompensated demand functions.

Like in the Rotterdam methodology, we can suppose that there exists a direct utility function related to consuming a bundle of commodities, $u = U(q)$, which is assumed to be twice-continuously differentiable, increasing, and quasi-concave in q. Assuming that consumers are price takers, consider the following optimization problem:

(3.66) $\quad MaxU(q) \quad s.t. \;\; p'q=1$

The Hotelling-Wold identity gives the normalized uncompensated inverse demand system $b(q)$. The result is as follows:

(3.67) $\quad p_u = \{dU(q)/dq\} / \left\{ \sum_i (dU(q)/dq_i) q_i \right\} \equiv b(q)$

Equation (3.67) is equivalent to equation (3.4). Inverse demands measure marginal utility or marginal willingness to pay for commodities by consumers. In equilibrium, marginal utility or marginal willingness to pay for a commodity equals its market price.

---

[27]Compensated inverse demand system:

$p^c = \dfrac{dD(u,q)}{dq} \equiv a(u,q)$, where $a(u,q)$ is conditioned on an unobservable utility.

Uncompensated inverse demand system:

$p^u = \dfrac{dU(q)}{dq} \equiv b(q)$, where $b(q)$ has an explicit closed form in terms of the observable quantity variable.

[28]McLaren, Rossitter, and Powell (2000) describes a way to overcome the limitations in incorporating prior ideas about the structure of preferences by using the cost function to generate Marshallian demand systems.

Solving equation (3.67) for q gives the uncompensated direct demand system: $q = h(p)$. Equivalently, it can be obtained explicitly from the normalized indirect utility function $V(p)$:

(3.68) $V(p) \equiv \max_{q} \{U(q) : p'q = 1\}$

by using Roy's identity. The result is as follows:

(3.69) $q = h(p) = \{dV(p)/dp\} / \left\{ \sum_{i} (dV(p)/dp) p_i \right\}$

Equation (3.69) is equivalent to equation (3.3).

The indirect utility function is continuous, decreasing, linearly homogeneous, and quasi-convex in p. Equations (3.67) and (3.69) show that the uncompensated inverse and direct demand systems have similar structures. However, while the inverse demand system takes quantities as exogenous, the direct demand system treats prices as exogenous. The duality between the direct and indirect utility functions suggests that the direct utility function can be recovered from the indirect utility function. That is,

(3.70) $U(q) \equiv \min_{p} \{V(p) : p'q = 1\}$

Given the direct utility function, the distance function $D(u,q)$ is defined as follows:

(3.71) $D(u,q) \equiv \max_{t} \{t > 0 : U(q/t) = u\}$

which gives the maximum amount by which commodity quantities must be deflated or inflated to reach the indifference surface (Shephard, 1970). The utility function exists if and only if $D(u,q) = U(q)/u = 1$. The distance function is continuous, increasing, linearly homogenous, and concave with respect to q, and decreasing in u. Given the distance function (3.71), the expenditure function $E(u, p)$ can be described as follows:

(3.72) $E(u,p)\equiv \min_{q}\{p'q{:}D(u,q)=1\}$

if and only if the distance function is defined as follows:

(3.73) $D(u,q)\equiv \min_{p}\{p'q{:}E(u,p)=1\}$

(Shephard, 1970). The expenditure function is continuous, increasing, linearly homogeneous, and concave with respect to p, and increasing in u. These results imply that the distance function can be interpreted as a normalized expenditure function and that the two functions are dual to each other.

Application of Shephard's lemma to the distance function yields the compensated inverse demand system $a(u,q)$:

(3.74) $p^{c}=dD(u,q)/dq\equiv a(u,q)$

dp in equation (3.7) could be also derived from equation (3.74).

Unlike uncompensated inverse demands, compensated inverse demands are defined with the level of utility held constant. Linear homogeneity of $D(u,q)$ implies that $a(u,q)$ is homogeneous of degree zero in q, which condition is equivalent to $Gq = 0$ in the Rotterdam methodology. The concavity implies that $a(u,q)$ is negative and symmetric, *i.e.*, $da(u,q)/dq < 0$ and $da_i(u,q)/dq_j = da_j(u,q)/dq_i$ $(i \neq j)$. Zero homogeneity of p^c implies

(3.75) $\sum_{i}\eta_{ij}^{c}=0$

where $\eta_{ij}^c \equiv d\ln a_i(u,q)/d\ln q_j$, compensated price flexibility , with $\eta_{ii}^c < 0$ and sign (η_{ij}^c) = sign(η_{ji}^c) $(i \neq j)$. Two goods *i* and *j* are net *q*-complements if $\eta_{ij}^c > 0$ and net *q*-substitutes if $\eta_{ij}^c < 0$. η_{ij}^c is corresponding to π_{ij} (or h_{ij}, c_{ij}) which is the substitution effect estimated by the Rotterdam methodology.

In addition, solving equation (3.74) for q implicitly gives the compensated direct demand system $q^c = h(u,p)$, which is equivalently obtained explicitly by applying Shephard's lemma to the expenditure function. The result is as follows:

(3.76) $q^c = h\ (u,p) = dE(u,p)/dp$

Thus the compensated inverse and direct demand systems have similar structures, the difference being whether prices or quantities are exogenous.

To derive the relationship between compensated and uncompensated inverse demands, equate $p^u = b(q)$ and $p^c = a(u,q)$ and substitute $u = U(q)$ into equation (3.74) to obtain

(3.77) $b(q) \equiv a(u,q) = a(U(q),q)$

Individual equation of equation (3.77) for commodity *i* can be expressed as follows:

(3.78) $b_i(q) \equiv a_i(u,q) = a_i(U(q),q)$

Now, partial differentiation of both sides of equation (3.78) with respect to q_j yields the Antonelli matrix of the price effect of a quantity change into the substitution and scale effects as follows:

(3.79) $\partial b_i(q)/\partial q_j = \partial a_i(u,q)/\partial q_j + (\partial a_i(u,q)/\partial u)(\partial U(q)/\partial q_j)$

In elasticity form, equation (3.79) becomes

(3.80) $\partial \ln b_i(q)/\partial \ln q_j = \partial \ln a_i(u,q)/\partial \ln q_j + (\partial \ln a_i(u,q)/\partial \ln u)(\partial \ln U(q)/\partial \ln q_j)$

$$\partial \ln a_i(u,q)/\partial \ln q_j = \partial \ln b_i(q)/\partial \ln q_j - (\partial \ln a_i(u,q)/\partial \ln u)(\partial \ln U(q)/\partial \ln q_j)$$

$$\eta_{ij}^c = \eta_{ij} - S_j \mu_i$$

where $\eta_{ij} \equiv \partial \ln b_i(q)/\partial \ln q_j$ is uncompensated price flexibility, and $\mu_i \equiv (\partial \ln a_i(u,q)/\partial \ln u)(\sum_i \partial \ln U(q)/\partial \ln q_i)$ is a scale flexibility, with S_j (expenditure share of the *j*th goods) = $p_j q_j = (\partial \ln U(q)/\partial \ln q_j)/(\sum_j \partial \ln U(q)/\partial \ln q_j)$. Two goods *i* and *j* are gross *q*-complements if $\eta_{ij} > 0$ and gross *q*-substitutes if $\eta_{ij} < 0$. For a normal good, a change in quantities has a negative scale effect, i.e., $\mu_i < 0$, with $\mu_i = -1$ for homothetic preferences. This implies that the uncompensated inverse demand is more quantity-elastic than the compensated inverse demand.

Since $\sum_i p_i q_i = \sum_i b_i(q) q_i = 1$, this implies the restriction on η_{ij}:

(3.81) $\sum_i \eta_{ij} S_i = -S_j$

Summing equation (3.80) over *j* to satisfy equation (3.75) and noting that $\sum_j S_j = 1$, we obtain the restriction on μ_i:

(3.82) $\mu_i = \sum_j \eta_{ij}$

which shows that the scale flexibility is obtained as the sum of the uncompensated price flexibilities. Moreover, summing equation (3.81) over *j*, we obtain the restriction on equation (3.82):

(3.83) $\sum_i S_i \mu_i = -1$

which says that the weighted sum of the scale flexibilities (with the weights given by the expenditure shares) is equal to -1. Equation (3.83) is equivalent to equation (3.15) and (3.32), $\sum_i h_i = -1$, equation (3.22) and (3.27), $\sum_i c_i = 0$, and equation (3.42), $\sum_i (\pi_i - \theta_1 w_i) = -1$ in the Rotterdam methodology.

Equation (3.80) shows that when the expenditure share of a good is small or when a change in quantities has no scale effects, i.e., $\mu_i = 0$, the uncompensated and compensated inverse demands coincide. An issue of great concern is under what condition a change in quantities has no scale effects. This occurs when the indirect utility function is quasi-linear. In the case of two goods, the quasi-linear indirect utility function is of the form:

(3.84) $V(p_1, p_2) = \alpha_1 f(p_1) + \alpha_2 p_2$

where indirect utility is linear in p_2 but nonlinear with respect to p_1, which implies that the (price) indifference curves are vertical translates of each other with respect to the p_2 axis.[29] Following equation (3.70), minimization of equation (3.84) with respect to p_1 and p_2 subject to $p_1 q_1 + p_2 q_2 = 1$ yields $\partial f(p_1)/\partial p_1 = \alpha_2 q_1 / \alpha_1 q_2$. This implies that the inverse demand for q_1 is independent of the scale of the quantities of q_1 and q_2, in which case the uncompensated and compensated inverse demands for q_1 coincide.

[29]A quasi-linear indirect utility function does not imply, nor is it implied by, the quasi-linear direct utility function which produces a zero income effect for the direct demand function.

3.2. Consumer Welfare Measurement

When quantity changes, consumers may be made better off or worse off depending on price and scale flexibilities which are estimated by one of either the Rotterdam methodology or distance function methodology. The classical economic measure of welfare change examined is consumer's surplus. However, consumer surplus can be an exact measure of welfare change only in special circumstances in which the utility function of consumers is quasilinear as the study previously discussed in equation (3.84). Therefore, more general methods for measuring welfare change are required. These general methods will include consumer's surplus as a special case.

If we can derive the inverse demand systems through using one of either the Rotterdam methodology or distance function methodology, it can provide the general method to exactly measure the change in consumer welfare. The theoretical review of the inverse demand systems in the previous section is motivated by our interest in the price and welfare effects of imports in fishery products. Typically, consumer welfare can be measured by consumer's surplus (*CS*) for which uncompensated flexibility is used, and compensating variation (*CV*) or equivalent variation (*EV*) for which compensated flexibility is used. As uncompensated flexibility overestimates the quantity effect on price, in which the quantity effect includes both substitution and scale effects, the consumer surplus is only an approximated measure. However, compensated flexibility exactly measures the quantity effect in which the scale effect can be separated from the substitution effect. As a result, compensating or equivalent variation can be used in this study to exactly measure the effect of imports on consumer welfare. Figure 3.4 shows *CV* and *EV* in quantity space. Furthermore, the difference between *CS* and *CV* or *EV* can be shown in Figure 3.5.

The flexibility estimated by the Rotterdam methodology or distance function methodology provides a useful method to measure not only new price but also consumer welfare resulted from change in quantity. For example, the new price resulting from a change in quantity can be calculated as follows:

$$(3.85) \quad p^1 = p^0 + \Delta p = p^0 \left[1 + (\textit{flexibility}) \times \left(\frac{\Delta q}{q^0} \right) \right]$$

where $\Delta q = q^1 - q^0$ is the change in quantity.

CV is associated with a change in quantity from q^0 to q^1. *CV* is calculated as follows:

$$(3.86) \quad CV = \Delta q \left[p^0 + 0.5 \left(\textit{comp.flexibility} \times \frac{p^0}{q^0} \right) \Delta q \right]$$

The area (*a*+*b*+*c*+*d*) in Figure 3.5 is *CV*. *CV* is the amount of additional (normalized) expenditure required for the consumer to reach the initial utility level, u^0, while facing the new quantity of q^1. When $q^1 > q^0$, *CV* measures the willingness to accept. The consumer is clearly better off while facing quantity q^1 if *CV* is greater than zero. In contrast, when $q^1 < q^0$, *CV* measures the willingness to pay. The consumer is clearly worse off with facing quantity q^1 of *CV* is less than zero.

The equivalent variation (*EV*) of a change in the quantity from q^0 to q^1 is calculated as follows:

$$(3.87) \quad EV = \Delta q \left[p^1 - 0.5 \left(\textit{comp.flexibility} \times \frac{p^0}{q^0} \right) \Delta q \right]$$

The area (a+b) in Figure 3.5 is *EV*. *EV* is the amount of additional (normalized) expenditure that would enable the consumer to maintain the new utility level u^1 while facing the initial quantity of q^0. When $q^1 > q^0$, *EV* measures the willingness to pay. The consumer is clearly worse off with facing quantity q^1 if *EV* is greater than zero. In contrast, when $q^1 < q^0$, *EV* measures the willingness to accept. The consumer is clearly better off with facing quantity q^1 if *EV* is less than zero. *CV* and *EV* are exact (normalized) measures of welfare change.

Figure 3.4 illustrates the *CV* and *EV* associated with an increase in the quantity of one good q_j. The indifference curve is defined over price space characterized by the indirect utility function (3.68). The slope of the budget line is the ratio of the commodity quantities- q_j / q_i. From Roy's identity, in equilibrium the slope of the (price) indifference curve is equal to the ratio of the quantities. The initial equilibrium is at *A*. With an increase in q_j, the new equilibrium occurs at *B*. Note that *CV* is conditional upon the utility level u^0, while *EV* is associated with the utility level u^1. When a change in quantities has no scale effects, the two welfare measures coincide. In general, the relationship between *CV* and *EV* cannot be ascertained.

Equations (3.85) and (3.86) suggest that *CV* and *EV* can be measured by the area under the compensated inverse demand curve from q^0 to q^1 with the old and new utility levels, respectively. For an increase in the quantity of one good, *j*, the compensated inverse demand curve $p_j^c = a_j(u^1, q)$ lies below the compensated inverse demand curve $p_j^c = a_j(u^0, q)$ because of the negative scale effect when the good in question is a normal good. This implies that *EV* is smaller than *CV* for an increase in the quantity of one good. This is illustrated in Figure 3.5.

In contrast to *CV* and *EV* which can be described by the compensated inverse demand function, consumer's surplus is expressed in terms of the uncompensated inverse demand functions. The quantity-based change in consumer surplus (*CS*) area (*a*+*b*+*c*), is bounded by *CV* and *EV* and is calculated as follows:

$$(3.88) \quad CS = \Delta q \left[p^0 + 0.5 \left(uncomp.flexibility \times \frac{p^0}{q^0} \right) \Delta q \right]$$

For a normal good, the uncompensated inverse demand curve is steeper than that of the compensated curve, implying that the *CS* associated with a change in quantities from q^0 to q^1 is bounded from below by the *CV* and from above by the *EV* - see Figure 3.5. When the scale flexibility is zero, *CS* coincides with *CV* and *EV*, *i.e.*, *CS* = *CV* = *EV*. When a change in quantity has a scale effect, however, *CS* will bias the true welfare change. For a normal good, the uncompensated inverse demand curve is steeper than the compensated curve implying that the *CS* associated with a change in quantities is bounded from below by the *EV* and from above by the *CV* so that (*EV* < *CS* < *CV*). Figure 3.5. portrays *CS* in relation to *CV* and *EV,* using the inverse demand curves. The price axis pertains to a range of implicit prices corresponding to the domain of quantities being considered. $a_j(u^0, q)$ and $a_j(u^1, q)$ are the two compensated inverse demand curves corresponding to initial and new utility levels u^0 and u^1 , while $b_j(q)$ is the uncompensated inverse demand curve. The initial situation is at A, given by p^0 and q^0. The final situation is at B, given by p^1 and q^1. *CV* is shown by the area *abcd* under the compensated inverse demand curve $a_j(u^0, q)$. *EV* is the area ab under the compensated inverse demand curve $a_j(u^1, q)$. *CS* is the area *abc* under the uncompensated inverse demand curve $b_j(q)$, which is bounded by *CV* and *EV*.

The *CS* is a relevant welfare measure for quantity changes when preferences are homothetic or when a quantity change has no scale effects. Homothetic preferences are, however, unrealistic, and commodity demands are found to have pronounced scale effects. Moreover, when many goods are considered, *CS* is not independent of the path of quantities chosen for integration since the associated uncompensated inverse demands are not symmetric in contrast to the compensated inverse demand functions associated with *CV* and *EV*. This implies that *CS* is approximate welfare measure for quantity changes relative to *CV* or *EV*. Nevertheless, *CS* is employed as the relevant measure for quantity changes, especially in analysis of social welfare or welfare properties of market equilibrium.[30]

[30]Hoteling (1938), in his pioneering study on welfare, addresses the relevance of total surplus defined as the sum of consumer and producer surpluses as a social welfare measure, and shows that the required condition is that the inverse demand and supply functions be integrable. The inverse supply or marginal cost functions are integrable because they are symmetric. In the case of demand, the integrability conditions hold only for the compensated inverse demand functions because they are symmetric. Hoteling, however, does not consider the compensated inverse demand functions. An implication of this discussion is that the conventional measure of total surplus based on the Marshallian consumer surplus derived from the uncompensated inverse demand function is biased in relation to the exact measure derived from the compensated inverse demand function.

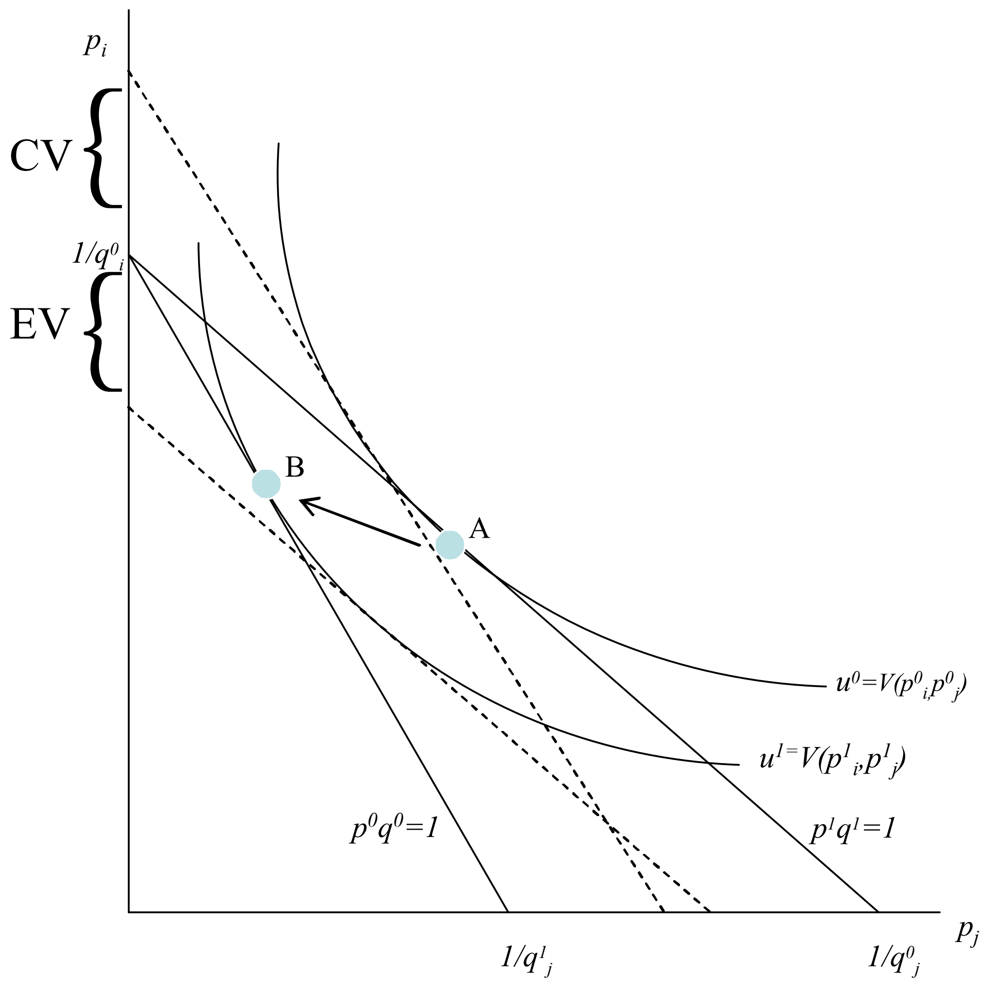

Figure 3.4. Compensating Variation and Equivalent Variation in Quantity Space.

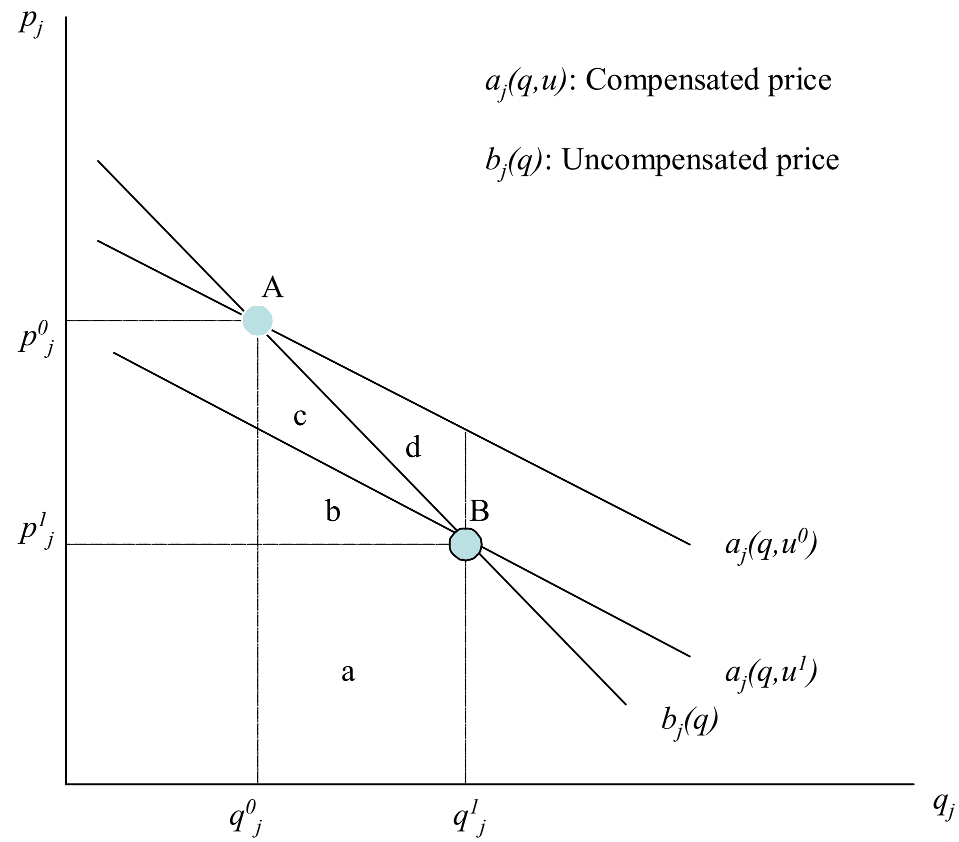

Figure 3.5. Welfare Measures of Change in Quantity.

3.3. Producer Welfare Measurement

As the producer's profit might be affected by a change in price caused by a change in quantity, producer welfare can be a critical issue related to the inverse demand systems. The welfare of the producer could be measured through dual cost and profit functions. For example, if there exists a production function assuming twice-continuously differentiable, increasing, and quasi-concave in x, a vector of inputs whose elements are x_i $(i = 1,...,n)$ and producer as price taker, the general form of the cost minimization equation can be defined as follows:

(3.89) $\quad Min\ r_i x_i \qquad s.t.\ q_j = F(x_i)$

where r_i is a vector of input prices and x_i is a vector of inputs.

Its solution, as summarized by the *Lagrangian* first order condition, gives the dual cost function,

(3.90) $\quad c = C(r_i, q_j)$

By using the given cost function, the cost flexibility, ψ_j can be obtained as follows:

(3.91) $$\psi_j = \frac{\partial C(r_i, q_j)}{\partial q_j} \cdot \frac{q_j}{C(r_i, q_j)}$$

Cost flexibility determines how a change in output level affects cost. That is, given constant input prices, the cost of the domestic producer would vary according to the level of production of q_j. To measure quantitatively the impact of producer profit caused by a change in quantity, a profit function is exemplified as follows:

(3.92) $\quad v_j = p_j \cdot q_j - C(r_i, q_j)$

In terms of short run, the profit will depend on the sign and size of price flexibility because the producer cannot respond to a change in price in the short run. Therefore, when p_j changes from p_j^0 to p_j^1, the change in producer's profit can be calculated as follows:

$$(3.93) \quad dv_j = v_j^1 - v_j^0 = \left[p_j^1 \cdot q_j^0 - C_0\left(r_i, q_j^0\right)\right] - \left[p_j^0 \cdot q_j^0 - C_0\left(r_i, q_j^0\right)\right] = dp_j q_j^0$$

Consequently, if $dp_j > 0$, the producer will be better off, while if $dp_j < 0$, the producer will be worse off.

In the long run, however, the price shock will be reflected in the production process. When p_j changes from p_j^0 to p_j^1, the change then in profit can be calculated as follows:

$$(3.94) \quad dv_j = v_j^1 - v_j^0 = \left[p_j^1 \cdot q_j^1 - C_j^1\left(r_i, q_j^1\right)\right] - \left[p_j^0 \cdot q_j^0 - C_j^0\left(r_i, q_j^0\right)\right] = (dp_j - dc_j) dq_j$$

As we see in equation (3.94), the change in profit will depend on the sign and magnitude of price flexibility along with cost flexibility. In general, cost flexibility is positive because an increase in output requires more labor and/or capital. For the case of $dp_j > 0$, the producer will increase the profit by increasing production whenever $dp_j > dc_j$. However, whenever $dp_j < dc_j$, the producer will reduce the profit by increasing production. For the case of $dp_j < 0$, the producer will reduce the profit by increasing production, while the producer will be better off by decreasing production.

CHAPTER 4

ECONOMETRIC METHODOLOGY

Prior to quantitative estimation of inverse demand systems as developed in the previous chapter, it is necessary to consider the stochastic properties of relevant econometric models in selecting a desirable model, in which the estimated, unknown parameters should be unbiased, consistent, and efficient. Especially as it is related to estimating the parameters of quantity variables in the inverse demand systems, the econometric model specification should be formed to reflect the features of stochastic procedure and the data used in the study. This includes contemporaneous correlation of disturbance terms in the equations of the system, singularity related to the adding up condition in the budget share equations, the autoregressive process in the time series data, and endogeneity in the inverse demand systems. In order to describe the stochastic process of an econometric model, a disturbance term is added to each budget share equation of the system. There is either an implicit or explicit correlation between the disturbances in individual budget share equations of the system because of the substitutability/complementarity of the fishery products used in the study. If the disturbances are correlated with each other, then any one of the single equation econometric models is not at least efficient.

Owing to this drawback, single OLS or even GLS is not the best method to estimate the parameters. Therefore, this study will basically use Zellner's SUR because it allows more flexible estimation than the single equation model. However, in using a SUR model, many other stochastic issues should be solved to get a consistent and efficient estimation. Related to the adding up condition in budget share equations, singularity is a critical problem because in that if the covariance matrix of disturbance terms is also singular it is not possible to use a SUR model to estimate the unknown parameters in the system of equations. In a later sub-section, the study will discuss that issue more in detail. Serial correlation should also be considered when specifying the econometric model because time series data of quantity and price for the fish were used in the study. Furthermore, autocorrelation will create difficulty in estimating the unknown parameters with singularity of the covariance matrix of disturbance terms of the system equations. Fortunately, Berndt and Savin (1975) thoroughly explained this issue. The study will discuss this in more detail using as a basis of Berndt and Savin's paper.

One of the distinguishing features of inverse demand systems is that quantity is predetermined. However, fish imports and domestic landings are presumed to respond to price incentives so that the tests for endogeneity would be in order to confirm whether or not the inverse demand system is more desirable than the regular demand system. Endogeneity can be tested utilizing the Wu-Hauseman test. Other related issues will also be discussed in the future.

4.1. Seemingly Unrelated Regression (SUR)

Given a set of regression equations, the problem of efficiently estimating regression coefficients should be considered. For each equation in the set, the classical ordinary least-squares method (applied equation-by-equation) yields the most efficient coefficient estimators. However, if the disturbance in each equation is correlated with each other, system of estimation procedure yields coefficient estimators, at least asymptotically, more efficient than single-equation least-squares estimators. In this subchapter, the study will discuss the stochastic description of the system estimator implying that the regression coefficients in all equations are estimated simultaneously.

In order to construct such estimators, the study will employ a restricted Seemingly Unrelated Regression (SUR). As Zellner (1962) described, SUR can be applied in the analysis of data provided by budget share study when regressions for several commodities are to be estimated. Further, we can restrict the parameters of variables used in the equations. For example, as we discussed in the previous chapter, adding-up, symmetry, and homogeneity conditions can also be imposed on SUR.

As a vehicle for introducing Zellner's SUR, let us define SUR as follows:

$$y_{it} = X_{it}\beta_{it} + \varepsilon_{it} \tag{4.1}$$

where $i = 1,2,...,M$, and $t = 1,2,...,T$. Therefore, y_{it} is a $MT \times 1$ vector of observations on the dependent variables, X_{it} is a $MT \times MK$ matrix with rank K of observation on K independent nonstochastic variables, β_{it} is a $MK \times 1$ vector of regression coefficients, and ε_{it} is a $MT \times 1$ vector of random error terms. Equation (4.1) may be written in matrix form as follows:

$$\underset{(MT \times 1)}{\begin{bmatrix} y_{11} \\ \vdots \\ y_{1T} \\ y_{21} \\ \vdots \\ y_{2T} \\ \vdots \\ y_{M1} \\ \vdots \\ y_{MT} \end{bmatrix}} = \underset{(MT \times MK)}{\begin{bmatrix} x_{11}^1 & \cdots & x_{11}^K & & & & & & & \\ \vdots & \vdots & \vdots & & & & & & & \\ x_{1T}^1 & \cdots & x_{1T}^K & & & & & & & \\ & & & x_{21}^1 & \cdots & x_{21}^K & & & & \\ & & & \vdots & \vdots & \vdots & & & & \\ & & & x_{2T}^1 & \cdots & x_{2T}^K & & & & \\ & & & & & & \ddots & & & \\ & & & & & & & x_{M1}^1 & \cdots & x_{M1}^K \\ & & & & & & & \vdots & \vdots & \vdots \\ & & & & & & & x_{MT}^1 & \cdots & x_{MT}^K \end{bmatrix}} \underset{(MK \times 1)}{\begin{bmatrix} \beta_{11} \\ \vdots \\ \beta_{1K} \\ \beta_{21} \\ \vdots \\ \beta_{2K} \\ \vdots \\ \beta_{M1} \\ \vdots \\ \beta_{MK} \end{bmatrix}} + \underset{(MT \times 1)}{\begin{bmatrix} \varepsilon_{11} \\ \vdots \\ \varepsilon_{1T} \\ \varepsilon_{21} \\ \vdots \\ \varepsilon_{2T} \\ \vdots \\ \varepsilon_{M1} \\ \vdots \\ \varepsilon_{MT} \end{bmatrix}}$$

We can compactly describe the system equation at time t as follows:

$$(4.2)\qquad \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_M \end{bmatrix} = \begin{bmatrix} X_1 & & & \\ & X_2 & & \\ & & \ddots & \\ & & & X_M \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_M \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_M \end{bmatrix}$$

Now, we write more briefly as follows:

$$(4.3)\qquad y = X\beta + \varepsilon$$

where $y = [y_1', y_2', ..., y_M']'$, $\beta = [\beta_1', \beta_2', ..., \beta_M']'$, $\varepsilon = [\varepsilon_1', \varepsilon_2', ..., \varepsilon_M']'$, and X represents the block-diagonal matrix on the r.h.s. of (4.2). The disturbance vector in (4.1) and (4.3) is assumed to have the following variance covariance matrix:

$$(4.4)\qquad V(\varepsilon_i) = \begin{bmatrix} \delta_{11}I & \delta_{12}I & \cdots & \delta_{1M}I \\ \delta_{21}I & \delta_{22}I & \cdots & \delta_{2M}I \\ \vdots & \vdots & \cdots & \vdots \\ \delta_{M1}I & \delta_{M2} & \cdots & \delta_{MM}I \end{bmatrix} = \begin{bmatrix} \delta_{11} & \delta_{12} & \cdots & \delta_{1M} \\ \delta_{21} & \delta_{22} & \cdots & \delta_{2M} \\ \vdots & \vdots & \cdots & \vdots \\ \delta_{M1} & \delta_{M2} & \cdots & \delta_{MM} \end{bmatrix} \otimes I = \sum_c \otimes I = \mathbf{\Omega}$$

where I is a unit matrix of order $T \times T$ and $\delta_{ii'} = E(\varepsilon_{it}\varepsilon_{it}')$ for $t = 1,2,...,T$ and i, i' $=1,2,...,M$. In a temporal, cross-section regression, t represents time and equation (4.3) implies constant variances and covariances from period to period as well as the absence of any auto or serial correlation of disturbance terms. The $\delta_{ii'}$ with $i = i'$ are then the variances (and with $i \neq i'$ the contemporaneous covariances of the disturbance terms (or dependent variables) for any time period.

In a single cross section budget share equation of each commodity where t represents the t'th budget share of each commodity, and individual share equation explains expenditure share on a particular commodity, δ_{ii} is the covariance between the disturbance term in the share equations for commodity i and that in the share equations for commodity i' while δ_{ii} is the variance of the disturbance term in the share equation for expenditure on commodity i.

The form of (4.4) implies that the δ_{ii}'s are the same for all budget shares and that there is no correlation between different budget shares' disturbances. The assumption is a very critical one related to singular equation and autoregressive process in using time series data in the budget share equations. If this assumption not satisfied, we will encounter problems in estimating the parameter vector for the budget share equations. Later, we will discuss this in more detail. Lastly, t stands for the particular point of time and the form of (4.3) is such that there is correlation between disturbances or dependent variables related to a particular point of time, t but not to a different point of time, s $(t \neq s)$. It is referred to as the "contemporaneous covariance matrix." The contemporaneous covariance might come from either the substitutability or complementarity of fish used in the study. Also disturbance variances and covariance are assumed to be constant from period to period.

4.2. SUR with Cross Equation Restrictions

We have discussed in the previous section, an unrestricted SUR framework under the assumption that the β_i's are unrelated across equations. When systems of equations are used in economics, especially for modeling budget share equations, there are often cross equation restrictions on the parameters. Such models can still be written in the general form covered in (4.3) and so they can either be estimated by system OLS or FGLS. We still refer to such systems as SUR systems, even though the equations are now obviously related, and system OLS is no longer OLS equation-by-equation. For example, consider the two-equation population model as follows:

(4.5) $$y_1 = \gamma_{10} + \gamma_{11} x_{11} + \gamma_{12} x_{12} + \beta_1 x_{13} + \beta_2 x_{14} + \varepsilon_1$$
$$y_2 = \gamma_{20} + \gamma_{21} x_{21} + \beta_1 x_{22} + \beta_2 x_{23} + \gamma_{24} x_{24} + \varepsilon_2$$

where we have imposed cross equation restrictions on the parameters in the two equations because β_1 and β_2 show up in each equation. We can put this model into the form of equation (4.2 or 4.3) by defining X and β appropriately. For example, define $\beta = [\gamma_{10}, \gamma_{11}, \gamma_{12}, \beta_1, \beta_2, \gamma_{20}, \gamma_{21}, \gamma_{24}]$' which we know must be an 8×1 vector because there are 8 parameters in this system. The order in which these elements appear in β is up to us, but once β is defined, X must be chosen accordingly. For each observation i, define the 2×8 matrix as follows:

(4.6) $$X = \begin{bmatrix} 1 & x_{i11} & x_{i12} & x_{i13} & x_{i14} & 0 & 0 & 0 \\ 0 & 0 & 0 & x_{i22} & x_{i23} & 1 & x_{i21} & x_{i24} \end{bmatrix}$$

Multiplying X by β gives equation (4.5).

In applications such as the previous example, it is fairly straightforward to test the cross equation restrictions, especially using the sum of squared residuals statistics. To obtain the statistic, we would use the unrestricted estimates to obtain $\hat{\mathbf{\Omega}}$, and then obtain the restricted estimates using $\hat{\mathbf{\Omega}}$. The statistic is calculated as follows:

(4.7) $$\left(\sum_{i=1}^{M} \tilde{\varepsilon}_i \hat{\mathbf{\Omega}}^{-1} \tilde{\varepsilon}_i' \right) - \left(\sum_{i=1}^{M} \hat{\varepsilon}_i \hat{\mathbf{\Omega}}^{-1} \hat{\varepsilon}_i' \right) \overset{a}{\sim} \chi_Q^2$$

where $\tilde{\varepsilon}_i$ denote the residuals from restricted system OLS (with Q restrictions imposed on β), $\hat{\varepsilon}_i$ is the residuals from unrestricted model, respectively. The statistic in (4.7) is the difference between the sum of squared residuals from the restricted and unrestricted models, but it is just as easy to calculate (4.7) directly. Gallant (1987) has found that an F

statistic has better finite sample properties. The F statistic in this context is defined as follows:

$$(4.8) \qquad F = \left[\left(\sum_{i=1}^{M} \tilde{\varepsilon}_i \hat{\mathbf{\Omega}}^{-1} \tilde{\varepsilon}_i' \right) - \left(\sum_{i=1}^{M} \hat{\varepsilon}_i \hat{\mathbf{\Omega}}^{-1} \hat{\varepsilon}_i' \right) \Big/ \left(\sum_{i=1}^{M} \hat{\varepsilon}_i \hat{\mathbf{\Omega}}^{-1} \hat{\varepsilon}_i' \right) \right] [TM - K] / Q$$

4.3. Singular Variance Matrices in SUR System

In the discussion so far we have assumed that the variance-covariance matrix, $\mathbf{\Omega}$, of ε_i is nonsingular. In budget share applications this assumption is not always true in the original structural equations because of the adding up condition. For example, let us suppose that there are three fishery products. Because of different prices and quantities consumed of each product, the individual budget share will be different. Now, define one particular set of the individual budget share equations in terms of the quantity as follows:

$$(4.9) \qquad \begin{aligned} w_1 &= \beta_{10} + \beta_{11} \ln q_1 + \beta_{12} \ln q_2 + \beta_{13} \ln q_3 + \varepsilon_1 \\ w_2 &= \beta_{20} + \beta_{12} \ln q_1 + \beta_{22} \ln q_2 + \beta_{23} \ln q_3 + \varepsilon_2 \\ w_3 &= \beta_{30} + \beta_{13} \ln q_1 + \beta_{23} \ln q_2 + \beta_{33} \ln q_3 + \varepsilon_3 \end{aligned}$$

where the symmetry restrictions (from consumption theory) have been imposed. For a SUR analysis we would assume that

$$(4.10) \qquad E(\varepsilon_i \mid q_i) = 0$$

where $\varepsilon_i \equiv (\varepsilon_1, \varepsilon_2, \varepsilon_3)'$ and $q_i \equiv (q_1, q_2, q_3)'$. Because the budget shares must sum to unity for each i, $\beta_{10} + \beta_{20} + \beta_{30} = 1$, $\beta_{11} + \beta_{12} + \beta_{13} = 0$, $\beta_{21} + \beta_{12} + \beta_{23} = 0$, $\beta_{31} + \beta_{32} + \beta_{33} = 0$, and $\varepsilon_1 + \varepsilon_2 + \varepsilon_3 = 0$. This last restriction implies that $\mathbf{\Omega} \equiv Var(\varepsilon_i)$ has rank two. Therefore, we can drop the last equation and analyze the equations for w_1 and w_2. We can describe the restrictions on β in these first two equations as follows:

$$(4.11) \qquad \begin{aligned} \beta_{13} &= -\beta_{11} - \beta_{12} \\ \beta_{23} &= -\beta_{21} - \beta_{22} \end{aligned}$$

Using the algebraic fact that $\ln(a/b)=\ln(a)-\ln(b)$, we can plug (4.11) into (4.9) to get

$$(4.12)\quad \begin{aligned} w_1 &= \beta_{10}+\beta_{11}\ln(q_1/q_3)+\beta_{12}\ln(q_2/q_3)+\varepsilon_1 \\ w_2 &= \beta_{20}+\beta_{12}\ln(q_1/q_3)+\beta_{22}\ln(q_2/q_3)+\varepsilon_2 \end{aligned}$$

We now have a two-equation system with variance matrix of full rank, with unknown parameters $\beta_{10}, \beta_{20}, \beta_{11}, \beta_{12}$, and β_{22}. To write this in the form (4.3), redefine $\varepsilon=(\varepsilon_1,\varepsilon_2)'$ and $w=(w_1,w_2)'$. Take $\beta=(\beta_{10},\beta_{11},\beta_{12},\beta_{20},\beta_{22})'$ and then X must be

$$(4.13)\quad X=\begin{bmatrix} 1 & \ln(q_1/q_3) & \ln(q_2/q_3) & 0 & 0 \\ 0 & 0 & \ln(q_1/q_3) & 1 & \ln(q_2/q_3 \end{bmatrix}$$

This formulation imposes all the conditions implied by inverse demand theory.

This model could be extended in several ways. The simplest of them would be to allow the intercepts to depend on commodity characteristics such as seasonality. For each commodity i, let z_i be a $1\times J$ vector of observable commodity characteristics, where $z_{i1}\equiv 1$. Then we can extend the model to

$$(4.14)\quad \begin{aligned} w_1 &= z_i\boldsymbol{\delta}_1+\beta_{11}\ln(q_1/q_3)+\beta_{12}\ln(q_2/q_3)+\varepsilon_1 \\ w_2 &= z_i\boldsymbol{\delta}_2+\beta_{12}\ln(q_1/q_3)+\beta_{22}\ln(q_2/q_3)+\varepsilon_2 \end{aligned}$$

where $E(\varepsilon_i \mid z_i, q_1, q_2, q_3)=0$.

Because we have already reduced the system down to two equations, theory implies no restrictions on $\boldsymbol{\delta}_1$ and $\boldsymbol{\delta}_2$. However, in equation (4.9), we need additional restrictions on parameters, $\boldsymbol{\delta}_i$ like $\boldsymbol{\delta}_1+\boldsymbol{\delta}_2+\boldsymbol{\delta}_3=0$.

4.4. Singular Equation Systems with Autoregressive Disturbances

In the previous section, the study showed that when disturbances are serially independent, SUR estimates of the parameters in the complete n-equation system can be derived from SUR estimation of n-1 equations: moreover, these SUR estimates are invariant to the equation deleted. However, Berndt and Savin (1975) found that the adding up property of shares imposes restrictions on the parameters of the autoregressive process. When these restrictions are not imposed, the specification of the model is conditional on the deleted equation. As a result, the SUR estimates of the parameters are no longer invariant to the deleted equation. Furthermore, singularity of the contemporaneous covariance matrix raises issues concerning the identification of parameters of the autoregressive process.

For example, let us suppose that the disturbance of (4.3) is a sample from a stationary vector stochastic process which satisfies the stochastic difference equation and each dependent variable has the same independent variables as follows:

(4.15) $y_t = X_t \beta + \varepsilon_t$

(4.16) $\varepsilon_t = R\varepsilon_{t-1} + e_t \qquad\qquad t = 2,\ldots,T$

where y_t is an $M \times 1$ vector of dependent variables, X_t is a $K \times 1$ vector of exogenous variables with unity as the first element, β is an $M \times K$ matrix of unknown parameters, and the sequence $e_2, e_3, \ldots,$ consists of independently identically distributed normal random vectors with mean vector zero and covariance matrix $\mathbf{\Omega}$ and where $R = [R_{ij}]$ is an $M \times M$ matrix of unknown parameters.

Here it is assumed that y_t satisfies the adding up condition

(4.17) $i' y_t = 1 \qquad (t = 1,\ldots,T)$

where i is an $M \times 1$ vector with all elements equal to unity. (4.15) and (4.17) imply

(4.18) $i' \beta = [1 \quad 0 \quad 0 \quad \cdots \quad 0]$

and

(4.19) $\quad i'\varepsilon_t = 0$

Since ε_{t-1} and e_t are statistically independent, it follows from (4.16) and (4.19) that

(4.20) $\quad i'R = k'$

and

(4.21) $\quad i'e_t = 0 \qquad (t = 1,...,T)$

Hence in the context of an autoregressive model the adding up condition (4.17) implies that each column of R must sum to the same unknown constant k and that $\mathbf{\Omega} i = 0$ which means that $\mathbf{\Omega}$ is singular. Furthermore, if R is specified to be diagonal, then the restriction of (4.20) requires that all diagonal elements be equal.

Now we delete the last equation from (4.15) and (4.16) gives

(4.22) $\quad y_t^M = \beta_M X_t + \varepsilon_t^M \qquad (t = 2,...,T)$

and

(4.23) $\quad \varepsilon_t^M = R_M \varepsilon_{t-1} + e_t^M \qquad (t = 2,...,T)$

where y_t^M and ε_t^M are the vectors y_t and ε_t with the last element deleted and β_M and R_M are the parameter matrices β and R with the last row deleted. Since R_M is not a square matrix (it has order $M-1\times M$), the SUR estimation procedure are not applicable to (4.22) and (4.23). However, this difficulty can easily be remedied. Since $i'\varepsilon_t = 0,$ we can rewrite the stochastic difference equation (4.16) as follows:

$$(4.24) \quad \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{Mt} \end{bmatrix} = \begin{bmatrix} R_{11}-R_{1M} & \cdots & R_{1M-1}-R_{1M} \\ R_{21}-R_{2M} & \cdots & R_{2M-1}-R_{2M} \\ \vdots & & \vdots \\ R_{M1}-R_{MM} & \cdots & R_{MM-1}-R_{MM} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t-1} \\ \varepsilon_{2t-1} \\ \vdots \\ \varepsilon_{M-1t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \\ \vdots \\ e_{Mt} \end{bmatrix}$$

or more compactly,

(4.25) $\varepsilon_t = \overline{R}\,\varepsilon_{t-1}^M + e_t \qquad (t = 2,...,T)$

where $\overline{R} = \begin{bmatrix} \overline{R}_{11} & \cdots & \overline{R}_{1M-1} \\ \overline{R}_{21} & \cdots & \overline{R}_{2M-1} \\ \vdots & & \vdots \\ \overline{R}_{M1} & \cdots & \overline{R}_{MM-1} \end{bmatrix}$ (it has order $M \times M-1$) and $\overline{R}_{ij} = R_{ij} - R_{ij}$

$(i=1,...,M; j=1,...,M-1)$.

From (4.20) and (4.25) it follows that all columns of $\overline{R}$ sum to zero, i.e.,

(4.26) $\overline{R}_{1j} + \overline{R}_{2j} + ... + \overline{R}_{Mj} = 0$

Now it is readily apparent that (4.22) combined with

(4.27) $\varepsilon_t^M = \overline{R}_M\,\varepsilon_{t-1}^M + e_t^M \qquad (t = 2,...,T)$

where $\overline{R}_M$ is the matrix $\overline{R}$ with the last row deleted, can be estimated using SUR procedure. Hence the parameter matrices β_M, $\overline{R}_M$, and $\mathbf{\Omega}_M$ have a unique SUR estimate and using these estimates we can obtain SUR estimates of the full parameter matrices β, $\overline{R}$ and $\mathbf{\Omega}$. To obtain invariant SUR estimates to the equation deleted, the R in (4.16) should be diagonal and $R_{11} = R_{22} = ... = R_{MM}$. If the R is diagonal and $R_{11} \neq R_{22} \neq ... \neq R_{MM}$, then the SUR estimates will vary with the equation deleted.

4.5. Endogeneity in Supply and Demand Framework

4.5.1. Demand Normalization and the Consistency of Least Squares

In models where demand adjusts to current price shocks but supply does not, the choice of the dependent variable is crucial for estimation and for economic interpretation. For example, the main motivation behind estimating an inverse demand system is that imports of fish are naturally taken to be predetermined. While fish supply is presumed to respond to price incentives, actual imports are not likely to be influenced by random disturbance in the short run price. However, one might question this assumption. Therefore, consider a model where price and quantity are determined simultaneously, in which it matters little whether either price or quantity is placed on the left-hand side in the demand equation. And then define the system of the demand and supply as follows:

(4.28) $\vartheta_1 q_t + \vartheta_2 p_t = X_t' \beta + e_t$: Demand

(4.29) $\varphi_1 q_t + \varphi_2 p_t = Z_t' \alpha + u_t$: Supply

(4.30) $E[X_t' Z_t']'[e_t u_t] = 0$

(4.31) $E[e_t u_t] = 0$

X_t and Z_t are column vectors of predetermined variables while β and α are conformable coefficient vectors. All other variables and coefficients are scalars. The demand shocks are assumed to be uncorrelated with the supply shocks.

There are two alternative restrictions on the system of equations (4.28) and (4.29) which predetermine supply. Each of the two implies its own normalization of demand. We have (i) direct demand equation and (ii) inverse demand equation as follows:

[*Direct Demand Equation*]

$\varphi_1 = 0$

(4.32)
$$q_t = (1/\vartheta_1) X_t' \beta - (\vartheta_2/\vartheta_1) p_t + (e_t/\vartheta_1)$$
$$q_t = \vartheta p_t + X_t' \beta_1 + e_{1t}$$

[*Inverse Demand Equation*]

$\varphi_2 = 0$

(4.33)
$$p_t = (1/\vartheta_2) X_t' \beta - (\vartheta_1/\vartheta_2) q_t + (e_t/\vartheta_2)$$
$$p_t = (1/\vartheta) q_t + X_t' \beta_2 + e_{2t}$$

q_t is predetermined in the inverse demand equation; it is decomposed by the supply equation into a function of observable predetermined variables and an unobservable variable which is uncorrelated with the demand disturbance. Similarly, the supply equation predetermines p_t in the direct demand equation.

The quantity-dependent equation (4.32) and the price-dependent equation (4.33) can be consistently estimated via ordinary least squares (OLS). If an estimate of ϑ is desired and the true structure is the inverse demand equation then the inverse of the OLS slope coefficient from the price-dependent equation is consistent for ϑ. Under the same circumstance, namely the truth of the inverse demand equation, OLS applied to a quantity-dependent demand equation is inconsistent for both ϑ and ϑ^{-1}, in which a more consistent technique would be to use an instrumental variables (*IV*) estimator on the quantity-dependent demand equation. This is inferior to the inverted, price-dependent OLS coefficient, on asymptotic variance grounds. Symmetric arguments hold if the inverse demand equation is true. Consistent estimators of ϑ are obtained from OLS on the price-dependent demand equation or from inverting the *IV* estimator from the quantity-dependent demand equation. OLS applied to the quantity-dependent demand equation is inconsistent for ϑ and for ϑ^{-1}.

4.5.2. Wu-Hausman Test

Consider a price-dependent demand equation wherein the endogeneity of the quantity variable is at issue. The null hypothesis is stated as the inverse demand equation restriction on the system of equations (4.28) – (4.31) as follows:

(4.34) $p_t = (1/\vartheta)q_t + X_t'\beta_2 + e_{2t}$

$H_0: Cov(q_t, e_{2t}) = 0 \ or \ \varphi_2 = 0$ in (4.29)

The Wu-Hausman test indicates the consistency of the restricted *SUR*, but the inconsistency of *IV*, under the null hypothesis. Specifically, the test measures the distance between the *SUR* and *IV* estimators standardized by a variance estimator that is consistent under the null hypothesis being tested. If the distance measured in this manner is large, the estimators are judged to have different probability limits and H_0 is deemed to be false. If the distance is small, one concludes that the *SUR* and *IV* estimators are converging to the same parameter and that H_0 is true – see Thurman (1986).

In order to describe the test's construction, let $\hat{\vartheta}$ be the estimator of ϑ from the restricted *SUR* regression and ϑ^* be an *IV* estimator of ϑ in the same inverse demand equation specification. Let $q=\hat{\vartheta}-\vartheta^*$. The Wu-Hausman statistic is defined as follows:

$$(4.35)\quad T=(\hat{\vartheta}-\vartheta^*)'[\hat{V}(q)]^{-1}(\hat{\vartheta}-\vartheta^*)\overset{a}{\sim}\chi^2_q$$

If $\hat{V}(q)$ is a consistent estimator of $Var(q)$ under H_0 the T is asymptotically chi-square.[31] The expression for T generalizes the demand equation example in that there could be more than one variable whose predeterminedness is questionable.

4.5.3. Interpreting Wu-Hausman Test Results in a Demand Equation

The test of the inverse demand equation is seen to be a comparison of two estimators of ϑ in (4.34). A large value for T rejects the null hypothesis of predetermined quantity and, in the present context, rejects predetermined supply. Notice that the particular notion of predetermined supply (direct demand equation or inverse demand equation from the previous section) is fixed by the normalization of the demand.

[31]Construction of the test is made simple by noting that, asymptotically, $Var(q)=Var(\vartheta^*)-Var(\vartheta)$ under H_0. See Hausman (1978) for a discussion.

A Wu-Hausman test in a price-dependent demand equation can only test for predetermined quantity, while in a quantity-dependent equation a Wu-Hausman test can only test for predetermined price. The difference in the two null hypotheses is the difference between a horizontal and a vertical supply curve. Consider the effects of performing the test in equation (4.34) if supply truly is predetermined, but predetermined in the sense of quantity supplied being unresponsive to current price. That is, assume the true structure to be the inverse demand equation.

The Wu-Hausman test in this instance involves a comparison between two estimators: the first being consistent and efficient under the null hypothesis of predetermined quantities, but inconsistent under the alternate hypothesis of endogenous quantities (the restricted *SUR* estimator) and the second being consistent under both null and alternate hypotheses (restricted three-stage least squares or 3SLS). To implement the 3SLS estimator requires instrumental variables not already included in the right-hand sides of the inverse demand equations and should be at least equal, in number, to the number of variables in question.

CHAPTER 5

EMPIRICAL RESULTS AND DISCUSSION

The inverse demand system approach is particularly useful in markets for fishery and natural resource commodities where quantities available are regarded as being predetermined rather than as being adjusted in the short run. In order to conduct empirical analyses, the raw data on quantities and nominal prices were collected from the different sources for each type of fish. The data for crawfish, shrimp, and oysters was obtained from the National Marine Fisheries Service while the catfish data came from the National Agricultural Statistics Service. The plots of quantity and nominal price are shown in Figures 5.1 to 5.10. As shown in Figure 5.1, the wide range in domestic crawfish tail meat supply in the 1990's is attributed to the variation in the captive and cultured harvests of live crawfish during this period. As Figure 5.2 shows, crawfish tail meat imports have contantly increased with slight fluctuations since 1990. Figure 5.3 and 5.4 show that there appears overall an upword trend in total supplies (domestic plus imported supplies) of both catfish and shrimp, respectively from 1980 to 2005. After peaking out in 1985, the total supply of oysters started decreasing and continued decreasing until 1992. However, since 1992 total oyster supply has increased. Domestic crawfish price tended to decrease between 1980 and 1995, then began increasing to levels that were generally above those of 1980 and continued increasing until 2001. However, crawfish domestic price decreased to 1980 level after 2001 (see Figure 5.6). Figure 5.7 shows the unit price for imported crawfish tail meat from 1989 to 2005. The unit price for imported crawfish tail meat was calculated by dividing the total value of imports by the total amount of imports. In particular, the unit prices of imported crawfish tail meat after 2001 include antidumping tariffs because of the high tariffs rate during these periods. Figure 5.8, 5.9, and 5.10 show the domestic prices of catfish, shrimp, and oysters, which are shown to more relatively stable than the domestic crawfish tail meat price. The price data were normalized before being used in the logarithmic equations of inverse demand systems. Quantities are divided by their sample mean before the logarithmic transformation. As a result, flexibilities will be estimated at quantity mean value.

Because estimation of a differential inverse demand system requires converting the differential terms to finite changes, logarithmic differences are computed between two consecutive years, and the averages of shares are taken for those same years. For instance, $d\ln p_i$ is approximated to be $d\ln p_i \equiv \ln p_{i,t} - \ln p_{i,t-1}$ and the approximation of w_i is $\overline{w}_i \equiv (w_{it} + w_{i,t-1})/2$, where subscript t indexes time. Furthermore, it is interesting to note that, unlike in continuous space, where $\sum_t w_i d\ln p_i = q'dp = -d\ln Q$ $\left(\because \sum_i w_i d\ln w_i = \sum_i dw_i = 0\right)$, the left-hand sides of the finitely approximated equations do not add up to exactly the same value as the right-hand sides, because $\sum_i \overline{w}_i \Delta\ln w_i \neq 0$. To maintain the adding up restriction, therefore, $d\ln Q$ are replaced with $\sum_i \overline{w}_i \Delta\ln p_i$ instead of $\Delta\ln Q$ in the finite approximation.

To estimate the parameters of the GIDS, specifications must be modified to reflect the discrete-time nature of the data and to accommodate for serial correlation in the system's disturbances. Equation (3.41) takes the following form:

(5.1) GIDS: $$\overline{w}_{it}\Delta\ln p_{it} = \alpha_i + \sum_{j=1}^{5}\pi_{ij}\Delta\ln q_j + \pi_i\Delta\ln Q - \theta_1\overline{w}_{it}\Delta\ln Q - \theta_2\overline{w}_{it}\Delta\ln(q_{it}/Q_t) + \varepsilon_{it},$$

where $\Delta \ln Q = \sum_{j=1}^{5} \overline{w}_{jt} \Delta \ln q_{jt}$ and $\overline{w}_{it} = \frac{w_{it} + w_{it-1}}{2}$.

Depending on the values of θ_1 and θ_2 in equation (5.1), equation (5.1) will be turned into DIRDS, DIAIDS, DICBS, and DINBR as follows:

(5.2) DIRDS: $$\overline{w}_{it} \Delta \ln p_{it} = \alpha_i + \sum_{j=1}^{5} h_{ij} \Delta \ln q_j + h_i \Delta \ln Q + \varepsilon_{it} \qquad (\theta_1 = \theta_2 = 0)$$

(5.3) DIAIDS: $$\Delta \overline{w}_{it} = \alpha_i + \sum_{j=1}^{5} c_{ij} \Delta \ln q_j + c_i \Delta \ln Q + \varepsilon_{it} \qquad (\theta_1 = \theta_2 = 1)$$

(5.4) DICBS: $$\overline{w}_{it} \Delta \ln \left(\frac{p_i^*}{P} \right) = \alpha_i + \sum_{j=1}^{5} h_{ij} \Delta \ln q_j + c_i \Delta \ln Q + \varepsilon_{it} \qquad (\theta_1 = 1, \theta_2 = 0)$$

(5.5) DINBR: $$\Delta \overline{w}_{it} - \overline{w}_{it} \Delta \ln Q = \alpha_i + \sum_{j=1}^{5} c_{ij} \Delta \ln q_j + h_i \Delta \ln Q + \varepsilon_{it} \qquad (\theta_1 = 0, \theta_2 = 1)$$

For estimation, the quantities are treated as exogenous, their covariance with current and lagged disturbance terms taken to be zero. Under these assumptions, the GIDS and the four other nested models can be estimated consistently using the generalized least squares estimator, or equivalently, SUR estimator. The assumption of predetermined quantities will be tested later using the Wu-Hauseman endogeneity test.

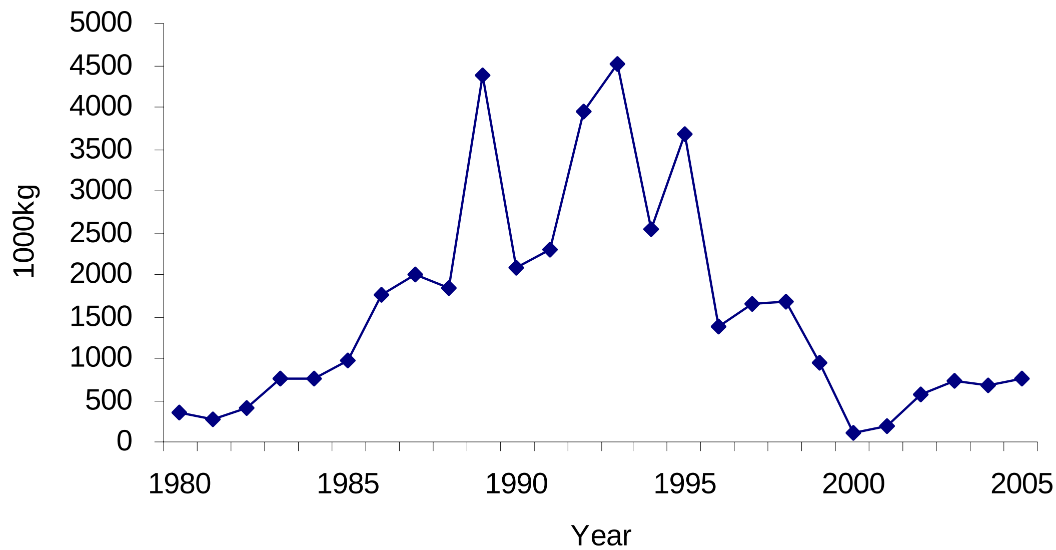

Figure 5.1. Domestic Crawfish Tail Meat Supply: 1980 – 2005.

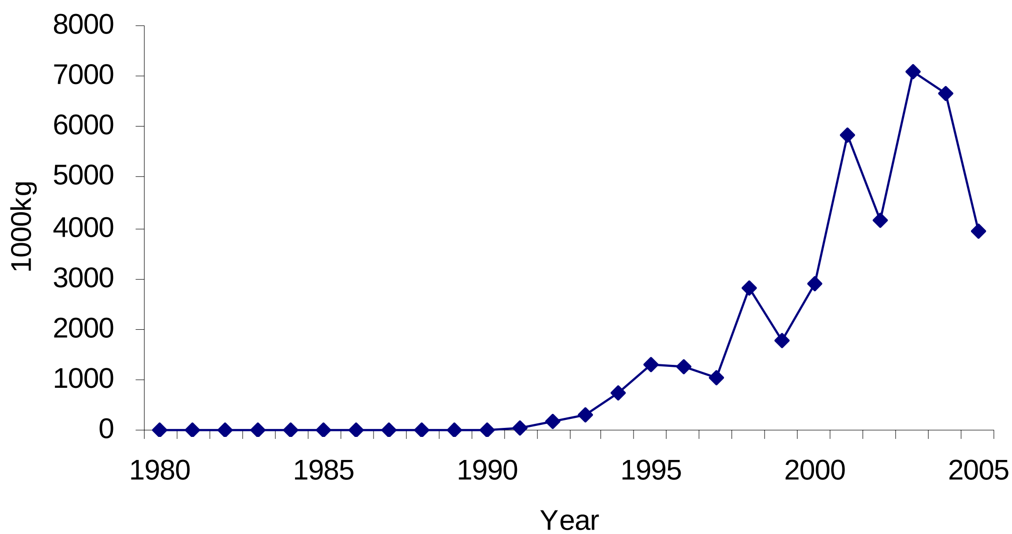

Figure 5.2. Imported Crawfish Tail Meat Supply: 1980 – 2005.

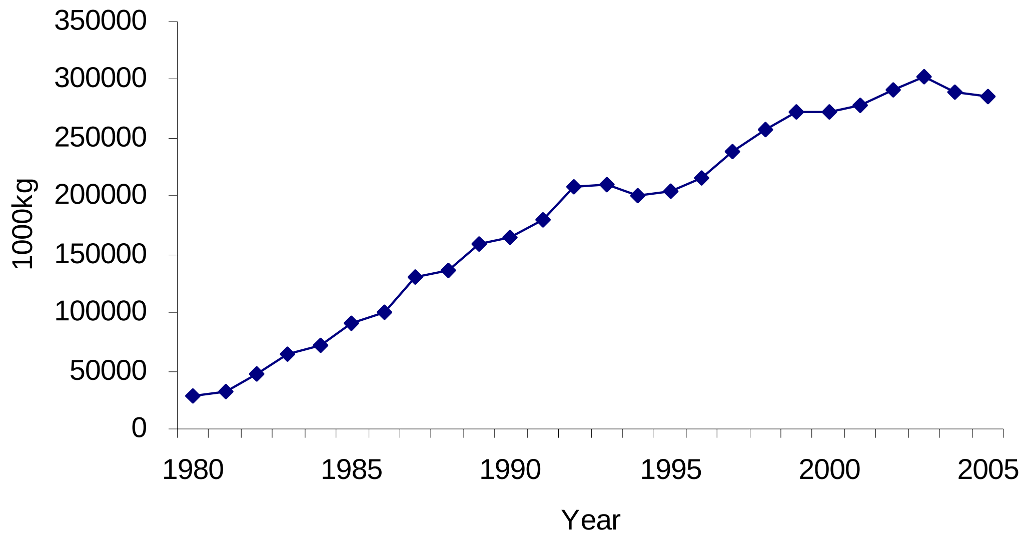

Figure 5.3. Catfish Supply: 1980 – 2005.

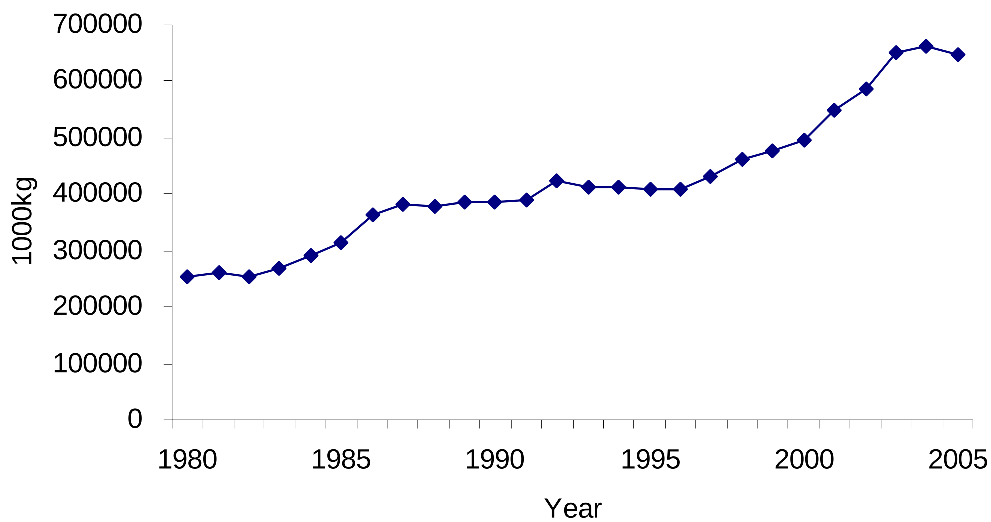

Figure 5.4. Shrimp Supply: 1980 – 2005.

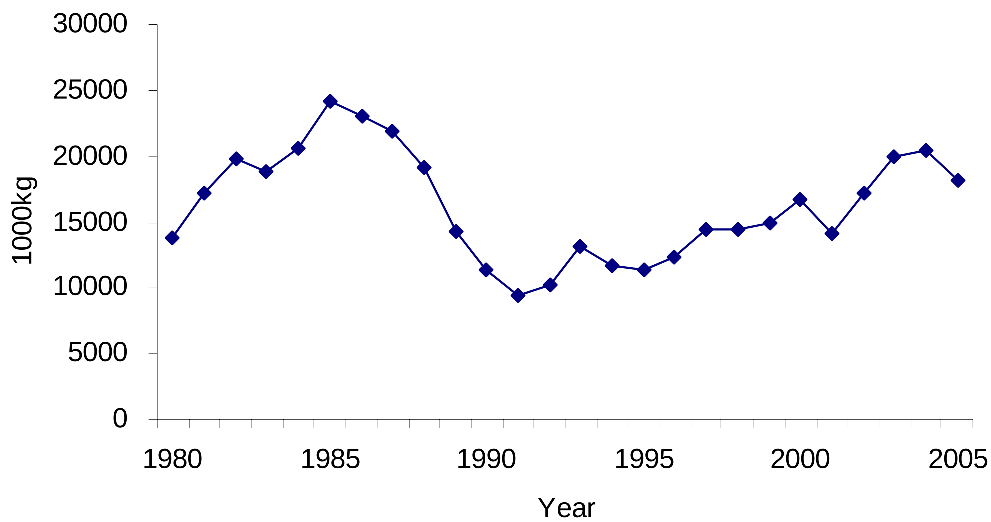

Figure 5.5. Oysters Supply: 1980 – 2005.

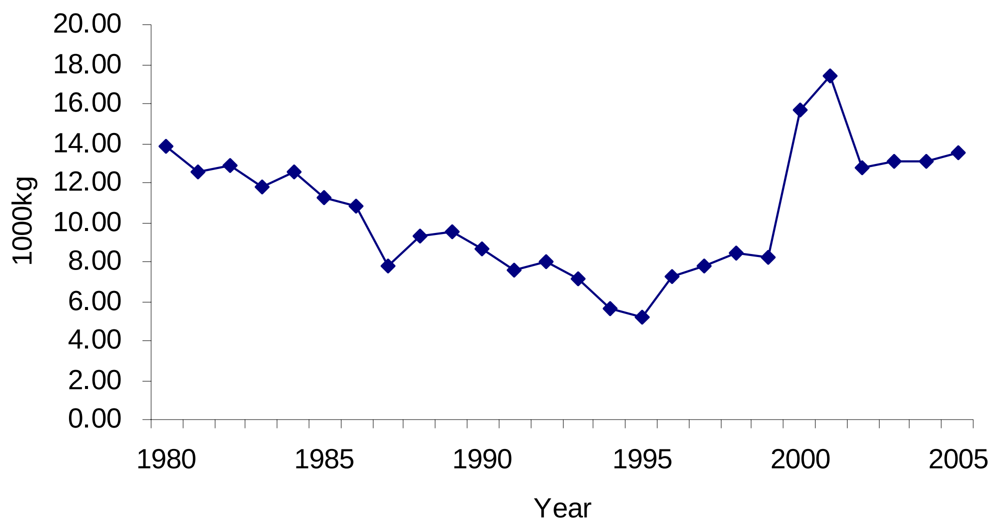

Figure 5.6. Domestic Crawfish Tail Meat Price: 1980 – 2005.

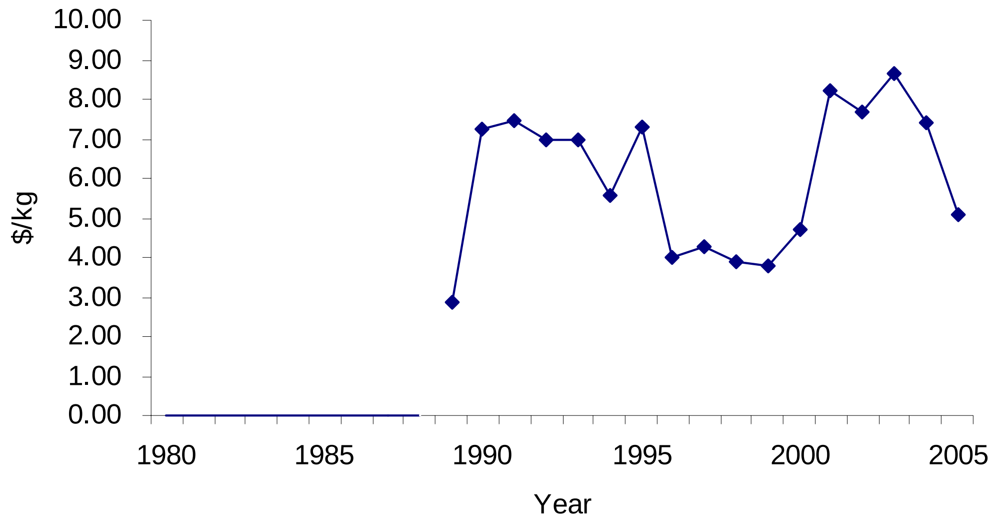

Figure 5.7. Imported Crawfish Tail Meat Price: 1980 – 2005.

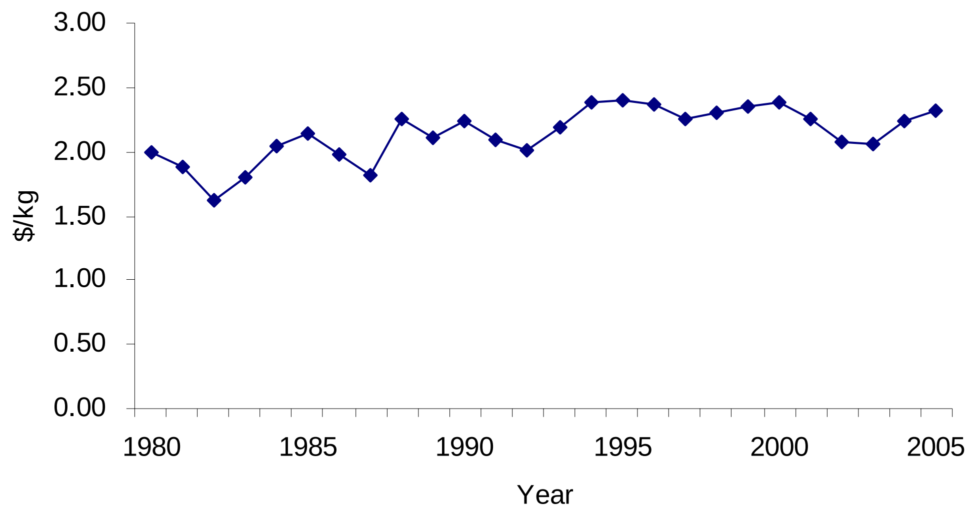

Figure 5.8. Domestic Catfish Price: 1980 – 2005.

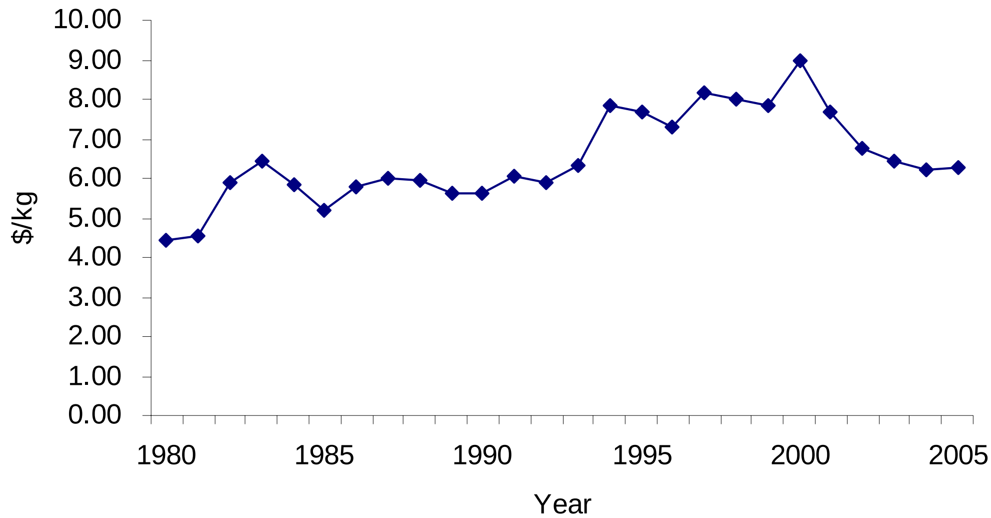

Figure 5.9. Domestic Shrimp Price: 1980 – 2005.

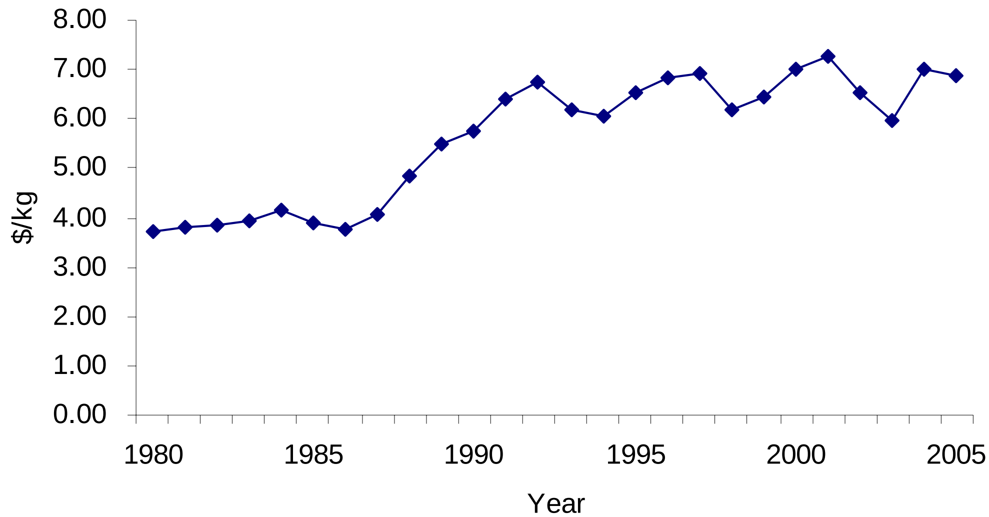

Figure 5.10. Domestic Oyster Price: 1980 – 2005.

The demand theory restrictions of the adding up, homogeneity, and symmetry conditions are imposed. Adding up implies singularity of the error variance-covariance matrix, $\mathbf{\Omega}$, because $\sum_{i=1}^{5}\varepsilon_{it}=0$. This can be imposed by dropping one of the equations as discussed in Chapter IV. Further, adding up implies the following parametric restrictions:

$$\sum_{i=1}^{5}\alpha_i=0 .$$

Symmetry and homogeneity of the π_{ij} , h_{ij} , and c_{ij} coefficients are also imposed.

Note that restricted SUR estimates of equation (5.1) to (5.5) are consistent and efficient if the disturbances are serially independent. However, if the disturbances are autocorrelated, SUR will not be efficient and the estimated standard errors will be inconsistent as discussed in Chapter IV. Thus, a transformed model is estimated by a FGLS procedure. Specifically, let the disturbances follow:

(5.6) $\varepsilon_{it}=\rho\varepsilon_{it-1}+u_{it} \qquad i=1,...,5$

In order to preserve the adding up condition, the autocorrelation coefficients are constrained to be the same in all equations (see Berndt and Savin, p.954, 1975). Thus, if the model detects serial correlation, then the FGLS procedure has three steps: (1) estimate equation (5.1) to (5.5) by SUR; (2) estimate ρ in equation (5.6) with the adding up restrictions from the SUR residuals; and (3) use the estimated parameters to transform the model according to the autoregressive FGLS formula and apply SUR to the transformed model.

5.1. Empirical Data

5.1.1. Preview of Empirical Data Properties

Table 5.1 shows the fish types, the average shares of total expenditure and quantity, and variations in expenditure and quantity over the sample periods, from 1980 to 2005.

Table 5.1. Fish Types, Shares and Variation in Total Expenditure and Quantity

Type of fish	Budget Share (w_i)				Qunatity (q_i)			
	Mean		Minimum	Maximum	Mean		Minimum	Maximum
	%	$1,000	$1,000	$1,000	%	1000kg	1000kg	1000kg
1. Crawfish (D)[a]	0.41	13,655	1,902	41,661	0.26	1,586	121	4,500
2. Crawfish (I)[b]	0.52	17,028	0	123,131	0.25	1,538	0	7,101
3. Catfish	11.84	390,784	55,688	649,938	28.76	177,872	27844	302,516
4. Shrimp	84.55	2,790,824	1,120,757	4,448,097	68.11	421,259	252917	661,732
5. Oysters	2.68	88,549	51,325	143,615	2.63	16,246	9399	24,086

[a] Indicates Domestic Crawfish Tail Meat
[b] Indicates Imported Crawfish Tail Meat

From Table 5.1 we see that shrimp is associated with the highest average share in total expenditure, at 84.55 percent. Catfish ranks second at 11.84 percent while other fish take only a relatively small portion of total expenditure ranging between 2.68 percent for oysters to 0.41 percent for domestic crawfish.

Average supplies by species, in 1000kg, are also reported in Table 5.1. Shrimp is associated with the highest average supply, at 421,259 thousand kg. Catfish ranks second at 177,872 thousand kg. Average supplies of domestic and imported crawfish are 1,586 and 1,538 thousand kg, respectively. Again there is considerable variation in quantity supplied and price. In all, there appears to be sufficient variation in the data so that it should be possible to determine what systematic relationships exist among the demand for these various fish products.

5.2. Testing Autocorrelation in a System Perspective

Table 5.2 contains the results of the system-wide specification test to assess the adequacy of the fitted AR1 residual serial correlation model for the five different inverse demand models used in the study. Edgerton and Shukur (1999) describe the Rao generalization to systems of the Breusch-Godfrey test for serial correlation (see Edgerton and Shukur, 1999, p346). Under the null hypothesis that an AR1 is an adequate specification, the Breush-Godfrey statistic is distributed as an $F(p,q)$ distribution, in which p is the number of restrictions and q is degrees of freedom of denominator (n - k). This study tested AR1 residual serial correlation for the five different inverse models using systemwise Breusch-Godfrey tests.

Table 5.2. Test Statistics of Serial Correlation for Inverse Demand Models

Model	Estimated	*Null*	*F*	*P-value*
GIDS	-0.03830	$H_0:\hat{\rho}=0$	0.02	0.8879
DIRDS	0.34778	$H_0:\hat{\rho}=0$	1.61	0.2254
DIAIDS	-0.37567	$H_0:\hat{\rho}=0$	2.20	0.1601
DICBS	0.06689	$H_0:\hat{\rho}=0$	0.06	0.8054
DINBR	-0.11533	$H_0:\hat{\rho}=0$	0.20	0.6609

Table 5.2 shows the results of the test statistic for the models. All models do not reject the null hypothesis of no serial correlation. Therefore, the coefficients will be estimated by SUR rather than FGLS.

5.3. Nested Tests of the Generalized Inverse Demand Model

It is important to determine which of the nested inverse demand systems, if any, fits the data. Thus, the study reports in Table 5.3, the estimated parameters θ_1 and θ_2 from equation (5.1). The parameters θ_1 and θ_2 are DIAIDS scale and substitution indicators. If $\theta_1 = \theta_2 = 1$, the GIDS reduces to the DIAIDS model. If $\theta_1 = \theta_2 = 0$, the GIDS reduces to DIRDS. As seen in Table 5.3, θ_1 and θ_2 are close to one, implying a DIAIDS form. Note, however, that θ_1 and θ_2 are both statistically distinguishable from the DIAIDS values of ones with showing relatively small standard errors of both θ_1 and θ_2.

Table 5.3. Estimated Mixing Parameters

Mixing Parameter	*Standard Error*
$\theta_1 = 1.04315$	(0.0245)
$\theta_2 = 0.85708$	(0.0448)

The study conducted joint likelihood ratio tests of the four hypotheses to confirm whether the estimated θ_1 and θ_2 are statistically different from one. As can be seen in Table 5.4, the results of joint likelihood ratio tests of the four hypotheses that restrict the GIDS to its constituent models reject the null hypotheses. Even though the estimated values of θ_1 and θ_2 suggest something like the DIAIDS model, the test restricting θ_1 and θ_2 to one in DIAIDS has a *p*-value of only 0.0033. These results are similar to those found by other recent works in quite different empirical applications. For example, Matsuda (2005) studied monthly Japanese fresh fish, meat, vegetables, and fruit consumption data, fitting data utilizing inverse demand systems. In this study it is indicated that the results of the Wald tests for nested models are adequate. Among the null hypotheses of θ_1 and θ_2 tested against the synthetic model. All four nested models, where both θ_1 and θ_2 are fixed, are strongly rejected. Park, Thurman, and Easley (2004) studied monthly fish consumption in the Gulf of Mexico and South Atlantic regions, inducing movements along inverse demand curves. They found that even though the estimated values of θ_1 and θ_2 suggest the DICBS model, the test results strongly rejected the null hypothesis.

Table 5.4. Test Statistics for Nested Models

Null	*F*
$\theta_1=0$	758
	(0.0001)
$\theta_1=1$	1.30
	(0.2593)
$\theta_2=0$	153
	(0.0001)
$\theta_2=1$	4.24
	(0.0438)
DIRDS	390
$(\theta_1=0, \theta_2=0)$	(0.0001)
DIAIDS	6.29
$(\theta_1=1, \theta_2=1)$	(0.0033)
DICBS	104
$(\theta_1=1, \theta_2=0)$	(0.0001)
DINBR	390
$(\theta_1=0, \theta_2=1)$	(0.0001)

Eales, Durham, and Wessells (1997) and Brown, Lee, and Seale (1995) showed additional examples. They fit the GIDS model and, like this study, can reject the sub-models such as DIRDS, DIAIDS, DICBS, and DINBR. But the mixing parameters estimated in this study are similar to those that result in the DIAIDS model, which is a different result from that of the other mentioned studies.

5.4. System Estimates

The main motivation for estimating an inverse demand system is that the supply of fishery products is naturally taken to be predetermined. While fish supply is presumed to respond to price incentives, actual imports and domestic supply are not likely to be influenced by random perturbations in that price. Still, one might question this assumption. Therefore, this study investigated the predeterminedness of quantities supplied with a pair of Wu-Hausamn tests. The Wu-Hausman test in this instance involves a comparison between two estimators: the first being consistent and efficient under the null hypothesis of predetermined quantities, but inconsistent under the alternate hypothesis of endogenous quantities (the restricted SUR estimator) and the second being consistent under both null and alternate hypotheses (restricted three-stage least squares or 3SLS). The Wu-Hausman test statistic based on this structural model had a value of 16.19, which is less than the 10% critical value in the chi-square (16) distribution of 23.54. In sum, neither test of the predeterminedness of quantities could reject the null hypothesis. The restricted SUR estimates reported in following tables are supported by this evidence.

In order to estimate quantity effects on price, the study estimates scale and Antonelli substitution coefficients by using the GIDS model as well as nested models such as DIRDS, DIAIDS, DICBS, and DINBR. As the results of these nested tests shows, the GIDS model is statistically fitted for these fish. However, this study estimates the scale and substitution coefficients of the four nested models as for reference.

5.4.1. Estimation of Scale Flexibility

Table 5.5.1 shows the results of the GIDS model. The last column of Table 5.5.1 gives the coefficients of determination (R^2) as an indicator for model fit and Durbin-Watson statistics as an indicator of first-order autocorrelation. The R^2-estimates are higher in the GIDS model than in any other of the nested models and none of the equations appear to have first-order autocorrelation in the GIDS model.

Look first at the estimated scale flexibilities in Table 5.5.1, which have all been estimated and are negative in sign. As the aggregate quantity increases, the normalized price goes down. This is to be expected. As Barten and Bettendorf (1989) explained, under the p_i^*, absolute prices stay constant, an increase in the aggregated quantity means an increase of total expenditure *m*, hence a decrease in $p_i = p_i^* / m$. The scale coefficients, π_i, can be converted into scale flexibilities by using equation (3.46). A value of -1 for the scale flexibility means that the relative price and the sales share are constant. If preferences are homothetic, all scale flexibilities would equal -1. The estimated values for the scale flexibilities of the considered products are given in Table 5.5.1 together with their approximate standard errors (in parentheses). The estimated scale flexibilities of domestic crawfish and oysters are insignificantly different from -1, suggesting homotheticity. However, the estimated scale flexibilities of imported crawfish, catfish, and shrimp are significantly different from -1, implying the underlying scale curves differ significantly from both linear and linear logarithmic forms.

5.4.2. Estimation of Compensated Price Flexibility

5.4.2.1. Own Compensated Price Flexibility

Now consider the estimated Antonelli substitution or Quantity effects of Table 5.5.1. The own price flexibilities have all been estimated negatively. One observes that these price flexibilities are relatively lower than that of Park, Thurman, and Easley (2004), Holt and Bishop (2002), Eales, Durham, and Wessells (1997), and Barten and Bettendorf (1989) but are about unit value except for catfish and shrimp. For example, a 1% increase in domestic crawfish quantity is associated with a 0.769% decline in domestic crawfish price. The negative sign of own price flexibilities is closely related to the negativity condition of Antonelli matrix. The estimated matrix is a negative semidefinite matrix. The absolute value of the own price flexibility of oysters is the largest among the five own price flexibilities, implying that the domestic oysters price is more sensitive to a change in own good than the other fishery products. For example, a 1% increase in the quantity of oysters is associated with a 1.085% decline in the domestic oysters price while 0.967% for imported crawfish, 0.554% for catfish, 0.102% for shrimp, declined, respectively. However, the estimated own compensated coefficients of domestic crawfish, imported crawfish, catfish, and shrimp are insignificantly different from zero at 10%, 5%, and 1% levels.

5.4.2.2. Cross Compensated Price Flexibility

For the Antonelli matrix off-diagonal elements, representing between-species substitution, 2 of the 10 cross effects are negative. A negative cross effect implies that the increase in quantity of one good reduces the marginal valuation of another good and induces consumers to consume less of that good. Notably, we see that imported crawfish is a substitute for domestic crawfish. A positive cross effect implies that the increase in quantity of one good raises the marginal valuation of another good and induces to consume more of that good. In this study, we see that the cross compensated price flexibilities of catfish, shrimp, and oysters are positive, implying catfish, shrimp, and oysters are complements to domestic crawfish. Among 10 cross effects, 5 cross effects are statistically significant at least at α=0.1. In particular, the cross effect of imported crawfish for domestic crawfish is statistically significant at α=0.05.

In order to precisely quantify the impacts of imported crawfish, catfish, shrimp, and oysters on the domestic crawfish price, we can use the cross compensated price flexibilities of these products. For example, the cross compensated price flexibility of imported crawfish, -0.378, indicates that a 1% increase in quantity of imported crawfish decreases the domestic crawfish price by 0.378%. The cross compensated price flexibility of catfish, 0.986, indicates that a 1% increase in quantity of catfish increases the domestic crawfish price by 0.986%. The cross compensated price flexibility of shrimp, 0.002, indicates that a 1% increase in quantity of shrimp increases the domestic crawfish price by 0.002%. The cross compensated price flexibility of oysters, 0.158, indicates that a 1% increase in quantity of oysters increases the domestic crawfish price by 0.158%.

The study confirms the negative impacts of imported crawfish on the domestic crawfish price. Furthermore, the scale flexibility of domestic crawfish, -1.24, indicates that a 1% increase in quantities of domestic and imported crawfish, catfish, shrimp, and oysters simultaneously decreases the domestic crawfish price by 1.24%. Although Table 5.5.1 shows that an increase in quantities of catfish, shrimp, and oysters has a positive relationship with the domestic price of crawfish, it can be deduced that an increase in aggregated fish supply has a strong negative impact on the domestic crawfish price from the result of scale flexibility.

5.4.3. Morishima Elasticity of Complementarity

As Barten and Bettendorf (1989) pointed out, interpreting similar results, "the small number of negative cross effects, of which in this study 2 cross effects are negative and 8 cross effects are positive, does not agree with the notion that most types of fish are mutual substitutes." However, the cross effects in the Antonelli matrix are biased toward complementarity. That is, each row of the Antonelli matrix must average to zero because of the property of homogeneity in the system of budget share equations and a good, being a "substitute for itself," has a negative own-price flexibility. As a result, complementarity dominates over substitutability in the off-diagonal terms.

While the tendency of the cross-price flexibilities toward complementarity is consistent with the more usual notion in a direct demand system that goods tend to be substitutes for one another, a standardized measure of substitutability is more useful than the price flexibilities themselves: the Morishima elasticity of complementarity.[32] It is the inverse demand system analogue of the Morishima elasticity of substitution. Table 5.6 presents the estimated elasticities from the flexibilities obtained by the GIDS model. The Morishima elasticity of complementarity is defined as $\sigma_{ij} = f^*_{ji} - f^*_{ii}$. It is the proportionate change in the j, i compensated demand price ratio due to a 1% increase in the ith quantity.

[32]In order to see why this is the case, consider the effect on the optimal quantity ratio, q_i/q_j induced by a percentage change in the price ratio, p_i/p_j. Suppose that this change is induced solely by changing the ith price. This will cause the compensated demands, including q_i, to change in a particular way. On the other hand, this same percentage change in the price relative can be induced by changing only the jth price; but all the compensated demands, including xj, will generally adjust differently in response to this price change. Hence, in general, the percentage change in the ratio, q_i/q_j, depends upon how this price relative, p_i/p_j, is changed (Blackorby and Russel, 1989).

Table 5.6 shows the proportionate change in domestic crawfish and other goods compensated demand price ratio due to a 1% increase in other goods quantity. For example, the imported/domestic crawfish value of 0.664 indicates that a 1% increase in the quantity of imported crawfish consumed results in a 0.664% increase in the ratio of the domestic crawfish demand price to the imported crawfish demand price, all other quantities and utility held constant. The catfish/domestic crawfish value is 0.588, indicating that a 1% increase in the quantity of catfish consumed results in a 0.588% increase in the ratio of the domestic crawfish demand price to the catfish demand price, all other quantities and utility held constant. The shrimp/domestic crawfish value is 0.102, indicating that a 1% increase in the quantity of shrimp consumed results in a 0.102% increase in the ratio of the domestic crawfish demand price to the shrimp demand price, all other quantities and utility held constant. The oysters/domestic crawfish value is 1.109, indicating that a 1% increase in the quantity of oysters consumed results in a 1.109% increase in the ratio of the domestic crawfish demand price to the oysters demand price, all other quantities and utility held constant. The elasticities of complementarity in Table 5.6 are all positive, reflecting both the tendency toward complementarity and the negativity of the own-price flexibilities.

5.4.4. Estimation of Uncompensated Price Flexibility

5.4.4.1. Own Uncompensated Price Flexibility

Uncompensated flexibilities are given in Table 5.7.1. The absolute values of own uncompensated flexibilities are greater than the absolute values of own compensated flexibilities because of negative values of scale flexibility and own compensated price flexibility. However, the absolute values of cross uncompensated flexibilities are dependent on the sign of the value of cross compensated price flexibility. If the cross compensated price flexibility is positive, then the absolute value of cross uncompensated price flexibility is less than the absolute value of cross compensated price flexibility, implying the scale effect reduce the substitution effect. As this study discussed in Chapter III, uncompensated price flexibility is the summation of both compensated price flexibility and scale flexibility. As a result, the uncompensated price flexibility represents the effects of scale and substitution as one. Table 5.7.1 shows the own uncompensated price flexibilities of five fish. The own domestic crawfish uncompensated price flexibility is estimated to be -0.774, implying a 1% increase in quantity of domestic crawfish decreases the domestic crawfish price by 0.774%. The own imported crawfish uncompensated price flexibility is estimated to be -0.980, implying a 1% increase in quantity of imported crawfish decreases the imported crawfish price by 0.980%. The own catfish uncompensated price flexibility is estimated to be -0.784, implying a 1% increase in quantity of catfish decreases the domestic catfish price by 0.784%. The own shrimp uncompensated price flexibility is estimated to be -1.895, implying a 1% increase in quantity of shrimp decreases the domestic shrimp price by 1.895%. The own oysters uncompensated price flexibility is estimated to be -1.131, implying a 1% increase in quantity of oysters decreases the domestic oysters price by 1.131%.

As seen in Tables 5.5.1 and 5.7.1, own goods are shown to have negative effects on their own price no matter what price is measured: compensated or uncompensated demand price. However, due to negativities of own price flexibility and scale flexibility the absolute magnitude of own uncompensated price flexibility is measured to be greater than own compensated price flexibility.

5.4.4.2. Cross Uncompensated Price Flexibility

The cross uncompensated price flexibilities for domestic crawfish are also shown in Table 5.7.1. The cross imported crawfish uncompensated price flexibility for domestic crawfish is estimated to be -0.384, implying that a 1% increase in quantity of imported crawfish decreases the domestic price by 0.384%. The cross catfish uncompensated price flexibility for domestic crawfish is estimated to be 0.840, implying that a 1% decrease in quantity of catfish increases the domestic crawfish price by 0.840%. The cross shrimp uncompensated price flexibility for domestic crawfish is estimated to be -1.047, implying that a 1% increase in shrimp quantity decreases the domestic crawfish price by 1.047%. The cross oysters uncompensated price flexibility for domestic crawfish is estimated to be 0.125, implying that a 1% decrease in quantity of oysters increases the domestic crawfish price by 0.125%. As seen in Tables 5.5.1 and 5.7.1, even though the cross compensated price flexibility of shrimp is positive, the uncompensated flexibilities turned out to be negative due to negative scale flexibilities of shrimp. In light of this, consumer surplus, which is related to the uncompensated flexibility, miscalculates the consumer welfare effect of quantity.

5.5. Welfare Measurements

The empirical work of the previous section is motivated by an interest in crawfish imports. While the benefits of crawfish imports might come from the consumer side, by way of lower domestic prices, the costs come from losses to domestic producers. Therefore, the study is intended to measure both the benefits and costs of crawfish imports. A theory of welfare measurement as to changes in quantity space has been developed by Barten and Bettendorf (1989), and this current section is an empirical counterpart to that work. The study evaluates the welfare effects of crawfish imports by calculating quantity-based compensating variations, consumer surplus and producer surplus.

In order to measure consumer welfare, the study uses consumer surplus and compensating variation based on uncompensated price flexibility and compensated price flexibility estimated in the empirical models. Producer welfare is calculated using change in net revenue of domestic crawfish processors. In measuring the change in net revenue of domestic crawfish processors, the study uses price flexibility, cost flexibility of domestic crawfish production, and quantity elasticity for imports of crawfish. Basically, this study assumes that crawfish tail meat imports will affect both domestic price and domestic production. The cost flexibility is estimated using crawfish processor cost data from 1994 to 2002 reported by U.S. International Trade Commission in 2003. The cost flexibility is estimated to be 1.6, representing a 1% increase in output increases cost by 1.6%, so that we see the domestic crawfish processors are not operating in economy of scale, which characterizes a production process in which an increase in the scale of the firm causes a decrease in the long run cost of each unit.

The import elasticity for domestic production is estimated using crawfish imports and domestic production during the same period with the cost flexibilities. It is estimated to be -0.057, representing that a 1% increase in crawfish imports decreases domestic crawfish production by 0.057%. For welfare measurements, initial domestic price is assumed to be the average price of the recent three years and the initial quantity of each fishery good is assumed to be the average of the recent three years.

5.5.1. Crawfish Imports Effects

Table 5.8.1 shows welfare changes for consumers, producers, and society depending on change in crawfish imports. As the study indicated in the previous chapters, it is the income effect that separates consumer surplus from compensating variation, and income effect is determined by scale flexibility. The difference between consumer surplus and compensating variation comes from the difference between uncompensated and compensated price flexibilities. As we see in Tables 5.5.1 and 5.7.1, there is little difference between own compensated price flexibility and own uncompensated price flexibility of domestic crawfish, indicating a small scale flexibility which determines the income effect. As a result, the consumer surplus shows that it is a reasonable approximation for exact welfare measurement of consumer related to a change in crawfish imports.

As expected, an increase in crawfish imports increases consumer welfare because both cross compensated and uncompensated price flexibilities of imported crawfish are negative. The result of the study shows that a 10% increase in crawfish imports increases consumer surplus by $3,628,000. The other four nested models: DIRDS, DIAIDS, DICBS, and DINBR models show similar results.

As mentioned previously, however, an increase in crawfish imports negatively affects domestic crawfish producers' income because of the negative price flexibility. Furthermore, in order to ease their loss along with decreasing prices, domestic crawfish processors should reduce volume of production. The empirical producer welfare change is calculated by using change in the net revenue of domestic crawfish processors. As Table 5.8.1 shows, an increase in crawfish imports decreases domestic crawfish processors' net revenue. For example, the result shows that a 10% increase in crawfish imports decreases domestic crawfish processor's economic welfare by $755,000. Unlike with consumer welfare, the four other nested models displayed different results, respectively.

In terms of net social welfare, the results of the study show that an increase in crawfish imports improves net social welfare because gains in consumer welfare are greater than the loss to producers'. Table 5.8.1 shows that an increase in crawfish imports increases net social welfare. For example, a 10% increase in crawfish imports increases net social welfare by $2,872,000. The four other nested models also show similar results with the exception that the dollar values are greater than those estimated in GIDS model.

Table 5.5.1. Scale and Compensated Price Flexibilities: GIDS

Equation	Scale Flexibility	Crawfish (D)	Crawfish (I)	Catfish	Shrimp	Oysters	R^2/DW
1. Crawfish (D)	-1.240 (0.899)	-0.769 (0.904)	-0.378 ** (0.126)	0.986 (0.545)	0.002 (0.001)	0.158 (0.151)	0.94 / 1.79
2. Crawfish (I)	-2.550 *** (0.680)	-0.303** (0.101)	-0.967 (2.844)	-0.414 (0.600)	1.975 (1.091)	-0.291* (0.153)	0.89 / 1.60
3. Catfish	-1.946 *** (0.472)	0.034 (0.019)	-0.018 (0.026)	-0.554 (0.494)	0.463 (0.320)	0.074 (0.049)	0.68 / 2.58
4. Shrimp	-2.120 *** (0.098)	0.000 (0.000)	0.012 (0.007)	0.065 (0.045)	-0.102 (0.091)	0.025 (0.063)	0.84 / 2.28
5. Oysters	-1.731 (0.890)	0.024 (0.023)	-0.056 (0.029)	0.327 (0.215)	0.790 (1.974)	-1.085* (0.500)	0.57 / 2.07

Note: Numbers in parentheses are standard errors.
* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

Table 5.5.2. Scale and Compensated Price Flexibilities: DIRDS

Equation	Scale Flexibility	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters	R^2/DW
1. Domestic (D)	-97.908*** (4.186)	0.555 (0.308)	-0.740 ** (0.322)	1.241 (0.730)	-1.201 (0.751)	0.144 (0.147)	0.46 / 1.13
2. Imports (I)	-113.706*** (3.805)	-0.593 ** (0.258)	0.724 * (0.334)	-0.473 (0.775)	0.857 (0.751)	-0.516*** (0.146)	0.87 / 1.13
3. Catfish	-1.997 *** (0.340)	0.043 (0.026)	-0.021 (0.034)	1.057 *** (0.190)	-1.149 *** (0.195)	0.069 ** (0.031)	0.67 / 1.60
4. Shrimp	0.200 *** (0.048)	-0.006 (0.004)	0.005 (0.005)	-0.161 (0.027)	0.172 (0.030)	-0.010 (0.005)	0.79 / 1.44
5. Oysters	2.203 *** (0.282)	0.022 (0.023)	-0.099 (0.028)	0.304 (0.139)	-0.325 (0.160)	0.098 (0.084)	0.53 / 1.25

Note: Numbers in parentheses are standard errors.
* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

Table 5.5.3. Scale and Compensated Price Flexibilities: DIAIDS

Equation	Scale Flexibility	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters	R^2/DW
1. Domestic (D)	-13.979 *** (3.938)	-1.088 (4.029)	-0.024 (0.238)	-0.322 (0.322)	1.562 (1.157)	-0.130 (0.142)	0.38 / 1.49
2. Imports (I)	4.746 (2.894)	-0.019 (0.191)	-0.274 * (0.146)	-1.074 ** (0.424)	1.244 (1.413)	0.123 (0.252)	0.76 / 0.99
3. Catfish	-1.767*** (0.430)	-0.011 (0.011)	-0.047 ** (0.018)	0.624 *** (0.039)	-0.373 *** (0.026)	-0.194*** (0.033)	0.87 / 0.97
4. Shrimp	-0.895 *** (0.239)	0.008 (0.006)	0.008 (0.009)	-0.052 *** (0.004)	0.012 *** (0.001)	0.025 (0.090)	0.80 / 0.60
5. Oysters	-0.014 ** (0.004)	-0.020 (0.022)	0.024 (0.048)	-0.855 *** (0.146)	0.796 (2.841)	0.055 (0.008)	0.77 / 2.45

Note: Numbers in parentheses are standard errors.
* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

Table 5.5.4. Scale and Compensated Price Flexibilities: DICBS

Equation	Scale Flexibility	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters	R^2/DW
1. Domestic (D)	3.475** (1.436)	0.027 (0.166)	-0.380 * (0.178)	-0.621 (0.647)	1.183 (0.783)	-0.210 (0.132)	0.31 / 1.85
2. Imports (I)	12.874 *** (3.547)	-0.304 * (0.143)	0.329 (0.417)	0.163 (0.740)	-0.031 (0.775)	-0.157 (0.152)	0.61 / 1.35
3. Catfish	-1.405 (1.098)	-0.022 (0.023)	0.007 (0.032)	-0.064 (0.167)	0.037 (0.177)	0.041 (0.027)	0.34 / 1.91
4. Shrimp	-1.044 (1.159)	0.006 (0.004)	0.000 (0.005)	0.005 (0.025)	-0.013 (0.028)	0.003 (0.004)	0.21 / 2.87
5. Oysters	-1.198 (1.641)	-0.032 (0.020)	-0.030 (0.029)	0.181 (0.120)	0.081 (0.133)	-0.199 ** (0.087)	0.27 / 1.86

Note: Numbers in parentheses are standard errors.
* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

Table 5.5.5. Scale and Compensated Price Flexibilties: DINBR

Equation	Scale Flexibility	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters	R^2/DW
1. Domestic (D)	27.055*** (0.362)	-1.240 (1.771)	-0.077 (0.296)	-0.367 (0.337)	1.802 (1.112)	-0.118 (0.139)	0.35 / 1.78
2. Imports (I)	57.668*** (0.383)	-0.062 (0.238)	-0.376 (0.258)	-1.000** (0.405)	1.280 (1.506)	0.157 (0.228)	0.68 / 2.11
3. Catfish	-0.508 ** (0.182)	-0.013 (0.012)	-0.044 ** (0.018)	0.677 *** (0.043)	-0.434*** (0.031)	-0.186 *** (0.033)	0.87 / 1.44
4. Shrimp	-0.437*** (0.032)	0.009 (0.005)	0.008 (0.009)	-0.061 *** (0.004)	0.020 *** (0.002)	0.024 (0.052)	0.96 / 1.79
5. Oysters	0.760 ** (0.299)	-0.018 (0.021)	0.030 (0.044)	-0.820 *** (0.146)	0.764 (1.625)	0.045 *** (0.007)	0.76 / 2.15

Note: Numbers in parentheses are standard errors.
* Indicates significance at 10% level.
** Indicates significance at 5% level.
*** Indicates significance at 1% level.

Table 5.6. Morishima Easticities of Complementarity

	Crawfish (D)	Crawfish (I)	Catfish	Shrimp	Oysters
Crawfish (D)	0.000	0.391	1.755	0.771	0.927
Crawfish (I)	0.664	0.000	0.553	2.942	0.676
Catfish	0.588	0.536	0.000	1.017	0.628
Shrimp	0.102	0.114	0.167	0.000	0.127
Oysters	1.109	1.029	1.412	1.875	0.000

Table 5.7.1. Uncompensated Price Flexibilities: GIDS

	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters
Domestic (D)	-0.774	-0.384	0.840	-1.047	0.125
Imports (I)	-0.313	-0.980	-0.716	-0.182	-0.359
Catfish	0.026	-0.028	-0.784	-1.182	0.022
Shrimp	-0.009	0.001	-0.186	-1.895	-0.032
Oysters	0.017	-0.065	0.122	-0.674	-1.131

Table 5.7.2. Uncompensated Price Flexibilities: DIRDS

	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters
Domestic (D)	0.150	-1.245	-10.350	-83.982	-2.482
Imports (I)	-1.064	0.138	-13.935	-95.281	-3.566
Catfish	0.035	-0.031	0.820	-2.837	0.015
Shrimp	-0.005	0.006	-0.137	0.341	-0.005
Oysters	0.031	-0.088	0.565	1.537	0.157

Table 5.7.3. Uncompensated Price Flexibilities: DIAIDS

	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters
Domestic (D)	-1.146	-0.096	-1.976	-10.256	-0.505
Imports (I)	0.001	-0.250	-0.512	5.256	0.251
Catfish	-0.019	-0.056	0.415	-1.867	-0.241
Shrimp	0.004	0.003	-0.158	-0.745	0.001
Oysters	-0.020	0.024	-0.856	0.784	0.055

Table 5.7.4. Uncompensated Price Flexibilities: DICBS

	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters
Domestic (D)	0.041	-0.362	-0.210	4.121	-0.117
Imports (I)	-0.251	0.396	1.687	10.854	0.188
Catfish	-0.028	0.000	-0.230	-1.151	0.003
Shrimp	0.001	-0.006	-0.118	-0.896	-0.025
Oysters	-0.037	-0.036	0.039	-0.931	-0.232

Table 5.7.5. Uncompensated Price Flexibilities: DINBR

	Domestic (D)	Imports (I)	Catfish	Shrimp	Oysters
Domestic (D)	-1.128	0.063	2.836	24.677	0.608
Imports (I)	0.177	-0.079	5.827	50.038	1.704
Catfish	-0.015	-0.046	0.617	-0.864	-0.199
Shrimp	0.007	0.006	-0.113	-0.350	0.013
Oysters	-0.015	0.034	-0.730	1.407	0.065

Table 5.8.1. Estimated Welfare Measures in $1000 from Increase of Crawfish Imports: GIDS

ΔCrawfish Imports		Consumer Welfare		Producer Welfare	Net Social Welfare	
(Δ%)	(Δton)	CS	CV	PS	CS+PS	CV+PS
1%	40	368	368	-76	292	292
2%	79	735	735	-152	583	583
3%	119	1101	1101	-227	873	873
4%	158	1465	1465	-303	1162	1162
5%	198	1829	1829	-379	1450	1450
10%	396	3628	3629	-755	2872	2873
20%	791	7137	7141	-1502	5635	5639
30%	1187	10527	10536	-2239	8287	8296
40%	1582	13798	13814	-2968	10830	10846
50%	1978	16951	16976	-3688	13263	13287
60%	2374	19985	20021	-4400	15585	15621
70%	2769	22901	22949	-5102	17798	17847
80%	3165	25697	25760	-5796	19901	19965
90%	3560	28375	28455	-6481	21894	21974
100%	3956	30934	31033	-7157	23777	23876

Table 5.8.2. Estimated Welfare Measures in $1000 from Increase of Crawfish Imports: DIRDS

ΔCrawfish Imports		Consumer Welfare		Producer Welfare	Net Social Welfare	
(Δ%)	(Δton)	CS	CV	PS	CS+PS	CV+PS
1%	40	367	368	-236	131	132
2%	79	730	733	-471	258	262
3%	119	1089	1096	-706	382	389
4%	158	1444	1456	-941	503	515
5%	198	1795	1815	-1176	619	639
10%	396	3495	3573	-2345	1150	1228
20%	791	6604	6917	-4661	1943	2255
30%	1187	9329	10032	-6949	2380	3083
40%	1582	11669	12918	-9208	2460	3710
50%	1978	13624	15576	-11439	2184	4137
60%	2374	15194	18005	-13642	1552	4363
70%	2769	16379	20205	-15815	563	4390
80%	3165	17179	22177	-17961	-782	4216
90%	3560	17594	23919	-20077	-2483	3842
100%	3956	17625	25434	-22166	-4541	3268

Table 5.8.3. Estimated Welfare Measures in $1000 from Increase of Crawfish Imports: DIAIDS

ΔCrawfish Imports		Consumer Welfare		Producer Welfare	Net Social Welfare	
(Δ%)	(Δton)	CS	CV	PS	CS+PS	CV+PS
1%	40	369	369	-22	346	346
2%	79	737	737	-45	692	692
3%	119	1105	1106	-67	1037	1038
4%	158	1472	1474	-90	1383	1385
5%	198	1840	1843	-112	1728	1731
10%	396	3672	3683	-224	3449	3460
20%	791	7315	7359	-445	6870	6914
30%	1187	10927	11028	-664	10263	10364
40%	1582	14511	14689	-881	13630	13808
50%	1978	18064	18343	-1096	16968	17247
60%	2374	21588	21989	-1308	20280	20681
70%	2769	25082	25628	-1519	23563	24110
80%	3165	28546	29260	-1727	26820	27533
90%	3560	31981	32884	-1933	30048	30951
100%	3956	35386	36501	-2137	33250	34365

Table 5.8.4. Estimated Welfare Measures in $1000 from Increase of Crawfish Imports: DICBS

ΔCrawfish Imports		Consumer Welfare		Producer Welfare	Net Social Welfare	
(Δ%)	(Δton)	CS	CV	PS	CS+PS	CV+PS
1%	40	368	368	-72	296	296
2%	79	735	735	-143	592	592
3%	119	1101	1101	-215	886	886
4%	158	1466	1465	-287	1179	1179
5%	198	1830	1829	-358	1471	1471
10%	396	3631	3628	-714	2917	2914
20%	791	7150	7139	-1420	5731	5719
30%	1187	10558	10533	-2117	8441	8416
40%	1582	13853	13809	-2806	11047	11003
50%	1978	17037	16968	-3487	13550	13481
60%	2374	20109	20010	-4160	15949	15850
70%	2769	23070	22934	-4824	18245	18109
80%	3165	25918	25741	-5480	20438	20260
90%	3560	28655	28430	-6128	22526	22302
100%	3956	31279	31002	-6768	24512	24234

Table 5.8.5. Estimated Welfare Measures in $1000 from Increase of Crawfish Imports: DINBR

ΔCrawfish Imports		Consumer Welfare		Producer Welfare	Net Social Welfare	
(Δ%)	(Δton)	CS	CV	PS	CS+PS	CV+PS
1%	40	369	369	7	376	376
2%	79	737	737	14	751	751
3%	119	1105	1105	21	1126	1126
4%	158	1473	1473	28	1501	1501
5%	198	1841	1841	35	1876	1875
10%	396	3677	3675	69	3746	3744
20%	791	7335	7326	137	7472	7463
30%	1187	10974	10954	203	11177	11157
40%	1582	14593	14557	268	14861	14825
50%	1978	18193	18137	331	18525	18469
60%	2374	21774	21693	393	22167	22086
70%	2769	25335	25225	454	25789	25679
80%	3165	28877	28734	513	29390	29247
90%	3560	32400	32218	571	32970	32789
100%	3956	35903	35679	627	36530	36306

CHAPTER 6

CONCLUSIONS AND FUTURE RESEARCH

6.1. Introduction

The crawfish industry in Louisiana has become an important portion of Louisiana's economy. Historically, whenever local crawfish harvests exceeded what could be moved through market channels to restaurants and retail consumers, excess product found its way to processing plants to be peeled and sold as fresh or frozen tail meat. This marketing outlet served to moderate drastic price swings and provided regional economic benefits in terms of adding value and creating employment. After the mid-1990s, however, these enterprises met a new face from low-priced imported crawfish tail meat, resulting in over all price instability not only for frozen tail meat but also for fresh tail meat and whole live and boiled crawfish. In fact, the International Trade Commission in 2003 reported that the Chinese imported crawfish tail meat had suppressed domestic processed crawfish prices to a significant degree. Substantial volumes of low-priced crawfish tail meat imports displaced sales of the domestic like product and, unable to meet those low prices, domestic producers responded by selling more fresh meat in season, selling more whole live crawfish, or scaling back production. Domestic crawfish producers experienced falling production and sales volume, capacity utilization, and employment, along with rising per-unit costs. The domestic crawfish industry suffered serious financial declines as falling sales volumes and rising costs erased profit margins. Furthermore, the domestic crawfish price may decline on account of increases in the availability of other fishery products as substitutes. Over the last decade the amount of fish imported into the U.S. market has increased considerably. A good example of this is the growth of shrimp imports and frozen catfish fillet imports. In 2004, U.S. shrimp imports were valued at $4 billion, representing 230% increase from 1989 when it was $1.7 billion. Thus, the domestic crawfish industry could be affected by other related fish imports.

In contrast, U.S. demand for crawfish has continued to grow since the mid-1990s. Demand growth is connected to a wider acceptance of crawfish as a food outside of Louisiana, and a growing national interest in Cajun cuisine. Some importers of crawfish stated that demand growth is due to the wider availability and lower prices associated with frozen Chinese crawfish tail meat. Increases in the consumption of crawfish leads one to conclude that domestic production capacity was not sufficient to supply domestic demand and this is why the volume of imports increased significantly. As a result, the market share of shipments of crawfish tail meat imports rose from 21 percent in 1994 to 83 percent in 2005.

One contribution of this study is to estimate a recently developed inverse demand system and use it to measure the welfare for the domestic crawfish industry. Unlike single equation models, the system-wide approach does not exclude substitution possibilities and includes interactions that are potentially important for understanding fish consumption patterns and price determination. This study applies the estimated system by analyzing welfare measures of change in quantity caused by imports.

6.2. Results

In order to measure the quantity effect on price, previous studies have developed inverse demand systems. These inverse demand systems have been developed using two primary approaches. The Rotterdam methodology determines the quantity effect on price in terms of scale and substitution effects while the distance function approach provides more information about utility and consumer preference. Since this study is intended to determine quantity effect on price, the study used the Rotterdam approach in developing inverse demand systems. The GIDS model is better suited for the data used in this study than the other four nested models. By using inverse demand systems, the study determined the substitution effect and scale effect of changes in quantity caused by changes in imports of crawfish and other related fish on the domestic crawfish price. Furthermore, using compensating price flexibility as a measure of the substitution effect of quantity and scale flexibility as a measure of the income effect, the study was able to provide welfare analyses for domestic crawfish consumers and producers. As expected, the study showed a negative effect of crawfish imports on the domestic price and producers welfare while the lower price caused by imports made domestic crawfish consumers better off. Related to other fish products, not all of fish used in the study proved to be substitutes for crawfish.

Scale effects have all been estimated to be negative, implying an increase in aggregate fish supply causes fish prices to decline, as was expected. However, the estimated scale flexibilities are significantly different from -1. Furthermore, test statistics show that the underlying scale curves differ significantly from both linear and linear logarithmic forms. This result suggests the need for better specification of utility function which can be more effectively described through distance function methodology.

Own price flexibilities have all been estimated as negative, implying an increase in own fishery production decreases the own price. This is to be expected. The negative own price flexibility is theoretically consistent because of the negativity of the Antonelli matrix. However, these price flexibilities estimated in the study are relatively lower than those of other studies. Among the five fish categories utilized in the study, the absolute value of own price flexibility for oysters is the largest, implying that domestic oyster price is more sensitive to change in the own good than for other fish.

Related to the cross price flexibility, this study confirmed the bias toward complementarity in the off-diagonal term of Antonelli matrix. However, as Barten and Bettendorf (1989) and Park, Thurman, and Easley (2004) showed, the small number of negative cross effects in this study does not agree with the notion that most types of fish are substitutes. Therefore, the Morishima elasticity of complementarity was proposed as a more adequate measure of interaction between commodities in their ability to satisfy needs than the coefficients of the Antonelli matrix. The study showed that elasticities of complementarity are primarily positive, implying both the tendency toward complementarity and the negativity of the own-quantity elasticities.

The study shows that the scale effect for crawfish is relatively small, implying that the consumer surplus can be used as a welfare measurement. In this study, the own crawfish compensated and uncompensated price flexibilities are estimated to be -0.769 and -0.774, respectively. As a result, the welfare effect does not show a difference between consumer surplus and compensating variation. However, the absolute values of cross uncompensated flexibility are different from that of cross compensated flexibility, depending on the sign of the cross compensated price flexibility.

This study was initially motivated to measure the effect of crawfish imports on the economic welfare of domestic crawfish industry. Estimating the price effect of quantity, such as price flexibility and scale flexibility obtained by using a family of inverse demand systems, this objective was accomplished. As expected, the result of the study shows that the domestic crawfish consumer experiences welfare gains while the domestic crawfish producer is worse off with increases in crawfish imports. The gains to the domestic crawfish consumers are greater than the loss to domestic crawfish producers, implying that the overall welfare of the domestic crawfish industry will be improved with increases in crawfish imports. However, even though the gains to domestic crawfish consumers are greater than the losses to domestic crawfish producers, the economic loss to domestic crawfish producers is quite serious because the loss is imposed on a small number of domestic crawfish processors. Such negative effects of crawfish imports on the domestic crawfish producers may be to blame for decreasing the number of domestic crawfish processors. Harrison et al. (2003) reported that, in 1996, there were estimated 90 to 100 crawfish processors in Louisiana; today there are approximately 15.

6.3. Implication

In evaluating the likely impact of crawfish and other related fish imports on the domestic crawfish industry, inverse demand systems provide a theoretically consistent method of analysis. In order to estimate flexibility as an indicator of the impact of imports on the domestic crawfish price, the generalized inverse demand system of Brown, Lee, and Seale was used with DIRDS, DIAIDS, DICBS, and DINBR. In terms of test statistics and economic theory, the GIDS model is better fitted for the actual data used in this study than any other models. The contribution of this study is to estimate recently developed inverse demand systems and use them to measure the welfare effect of increases in imports of crawfish and other related fish. As the study indicated, by using such a system-wide approach the study can also detect substitutability and interactions that are potentially important for understanding fish consumption patterns and price relationships. In particulation, substitutability implies that the domestic crawfish price can also be affected negatively by substitutable fish which are detected by this study. Thus, it would be useful to develop a policy tool in light of the negative relationship between domestic crawfish price and substitutable fish imports. Up until now, domestic policy has focused on own crawfish imports. However, this study has shown that other related fish supply also have negative impacts on the domestic crawfish price. Even though substitutability is shown to vary depending on the model, imported crawfish is shown to be a substitute for domestic crawfish in each of the models, GIDS, DIRDS, DIAIDS, DICBS, and DINBR. Furthermore, the scale flexibility also implies the negative impact of increases in the aggregate fish imports on domestic crawfish price. This result may have implication regarding the impact of the antidumping and counter-vailing duty on crawfish tail meat imports and its effect on the domestic crawfish price.

Quantitative measurement of welfare is another product of this study. The price flexibilities and scale flexibilities estimated in the inverse demand systems can be used as a tool to quantitatively measure welfare change caused by increases in imports of crawfish and other related fish. The welfare effects of quantity changes are associated with the inverse demand system in which commodity prices are dependent on their quantities. In particular, quantity-based welfare measures are useful in situations where supply is inelastic in the short run and the producers are price takers. This study showed that, although the gains to domestic crawfish consumers are greater than the losses to domestic crawfish producers, the economic burden imposed on the domestic crawfish producers is serious given that a small number of domestic crawfish processors bear the economic loss caused by increases in Chinese crawfish tail meat imports. In fact, this economic burden has reduced the number of domestic crawfish processors in Louisiana.

The findings in this study suggest that since increases in crawfish imports negatively affect domestic crawfish prices, and since producer losses are concentrated among a small number of domestic crawfish processors, the economic policy for preserving the domestic crawfish industry should be developed to reflect these results.

6.4. Limitations

This study determined the economic impact of imports of crawfish and other related fish on the domestic crawfish industry. The systems-wide model approach gives theoretically consistent results but the main concern with the study come from the data quality.

Secondly, even though there may be a relationship between crawfish price and other fish and/or red meat this study did not include all of them because of the size limitations of the inverse demand system. The omission of relevant products in the system may distort consumer preference and utility related to seafood consumption.

Related to analysis of domestic crawfish producer welfare, the cost flexibilities and import elasticities will differ according to cost structure in the activation of individual domestic processors. For example, if marginal cost is lower than the imported price, the domestic industry will produce more with increased domestic demand, while individual processors with higher marginal costs will reduce their level of production. This implies that precise information regarding production functions and cost structure of domestic crawfish producers would be useful.

6.5. Future Research

The Trade Adjustment Assistance Program allows the Secretary of Agriculture to compensate certain growers for economic damages incurred when imports have materially reduced domestic prices. The imported good must, even if lightly processed, be a close substitute for the domestic product. Compensation may be warranted if imports have brought domestic prices between 80% of the five-year, 1998 – 2002 average price. According to the results of the study, the imported crawfish is shown to reduce domestic prices. Furthermore, the negative scale effect of domestic crawfish indicates that increases in aggregated fish supply also have negative impact on domestic crawfish price. As a result, increases in fish imports, including crawfish and other related fish used in the study, affect domestic crawfish producers as shown in the results of this study. However, this analysis does not provide information regarding the economic impact of imports of crawfish and other related fish on individual domestic crawfish processors. Furthermore, since domestic crawfish farmers and wild harvesters are also affected by imports, it would be useful to extend this research to measuring the economic impacts of imports on individual crawfish producers including crawfish farmers and wild harvesters.

Related to government policy, since 1997 the government has imposed antidumping duties on Chinese imported crawfish tail meat. Since 2001, the Byrd Amendment has directed the U.S. Bureau of Customs and Border Protection to distribute the monies collected to domestic crawfish processors that had petitioned or supported antidumping and countervailing duty actions. However, under current policy, many domestic crawfish producers complain that this policy does not work. In fact, this policy focuses only on Chinese imported crawfish tail meat. As shown in this study, imports, not only of crawfish but also other related fish are closely related with the declining domestic crawfish price. As a result, to encourage the domestic crawfish industry it is essential to analyze production, cost structure, and current policy including, but not limited to: (1) declines in output, sales, market share, profits, productivity, return on investments, and utilization of capacity; (2) negative effects on cash flow, inventories, employment, wages, growth, ability to raise capital, and investment; and (3) negative effects on the existing development and production efforts of the industry.

As previous research indicates, red meat can also substitute for crawfish as a protein source. Changes in the prices of chicken, beef, and pork can affect crawfish consumption. According to the USDA (2005), the prices for chicken, beef, and pork are forecast to be lower in 2006 and to fall even lower again in 2007. These forecasts for lower prices of the major livestock and poultry protein sources indicate strong competition for domestic and imported crawfish consumption. Furthermore, according to the U.S. International Trade Commission (2003), there are many other factors affecting fish consumption. For example, quality and availability are another important factors that influence purchasing decisions for crawfish. Survey results show that price is an important factor for most purchasers, but often come after quality in importance. These factors indicate that consumer decision making process should be researched. Additional knowledge related to qualitative data analysis will assist in achieving this goal.

6.6. Conclusions

This research quantitatively determined the price and welfare effects of imports of crawfish. Inverse demand systems were used to estimate price and scale flexibilities as indicators of the effects of imports of crawfish on the domestic crawfish price. Among the different types of inverse demand systems, the generalized inverse demand model was shown to be best fitted for the data used in the study. As expected, the own price flexibility and scale flexibility are shown to be negative, while cross price flexibilities show either substitutability or complementarity relationships. Consumer welfare is measured by consumer surplus and compensating variation calculated by uncompensated and compensated price flexibility, respectively. Even though consumer surplus theoretically overestimates the quantity effect on welfare, empirical results show that there is little difference between consumer surplus and compensating variation related to crawfish imports because of the small scale effect in crawfish. Producer welfare is measured using price and cost flexibility in the profit function. Even though the economic loss to domestic crawfish producers resulting from the increase in imports of crawfish is relatively small compared with the gains to the domestic crawfish consumer, the impact of imports of crawfish are significant to domestic crawfish producers given that the loss is borne by a small number of domestic crawfish producers. However, this study shows a net social welfare gain through increased crawfish imports.

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APPENDIX I. DATA VARIABLE DEFINITION

Variables	Abbreviation
Crawfish Domestic Supply, 1000kg	crds
Crawfish Domestic Price, $/kg	crdp
Crawfish Imports, 1000kg	crms
Crawfish Imports Price, $/kg	crmp
Catfish Total Supply, 1000kg	cats
Catfish Domestic Price, $/kg	cadp
Shrimp Total Supply, 1000kg	shts
Shrimp Domestic Price, $/kg	shdp
Oysters Total Supply, 1000kg	oyts
Oysters Domestic Price, $/kg	oydp
Expenditure for Domestic Crawfish	wcd
Expenditure for Imported Crawfish	wcm
Expenditure for Catfish	wca
Expenditure for Shrimp	wsh
Expenditure for Oysters	woy
Total Expenditure for Crawfish, Catfish, Shrimp, and Oysters	w
Normalized Domestic Crawfish Price	ncrdp
Normalized Imported Crawfish Price	ncrmp
Normalized Domestic Catfish Price	ncadp
Normalized Domestic Shrimp Price	nshdp
Normalized Domestic Oysters Price	noydp
Normalized Domestic Crawfish Supply	ncrds

APPENDIX I. (Cont.)

Variables	Abbreviation
Normalized Imported Crawfish Supply	ncrms
Normalized Catfish Supply	ncats
Normalized Shrimp Supply	nshts
Normalized Oysters Supply	noyts
Log Normalized Domestic Crawfish Supply	lnncrdp
Log Normalized Imported Crawfish Supply	lnncrmp
Log Normalized Catfish Suppy	lnncadp
Log Normalized Shrimp Supply	lnnshdp
Log Normalized Oysters Supply	lnnoydp
One Year Lagged Log Normalized Domestic Crawfish Supply	laglnncrdp
One Year Lagged Log Normalized Imported Crawfish Supply	laglnncrmp
One Year Lagged Log Normalized Catfish Supply	laglnncadp
One Year Lagged Log Normalized Shrimp Supply	laglnnshdp
One Year Lagged Log Normalized Oysters Supply	laglnnoydp
Difference Log Normalized Domestic Crawfish Supply	dlnncrdp
Difference Log Normalized Imported Crawfish Supply	dlnncrmp
Difference Log Normalized Catfish Supply	dlnncadp
Difference Log Normalized Shrimp Supply	dlnnshdp
Difference Log Normalized Oysters Supply	dlnnoydp
Normalized Expenditure for Domestic Crawfish	nwcd
Normalized Expenditure for Imported Crawfish	nwcm
Normalized Expenditure for Catfish	nwca

APPENDIX I. (Cont.)

Variables	Abbreviation
Normalized Expenditure for Shrimp	nwsh
Normalized Expenditure for Oysters	nwoy
One Year Lagged Normalized Expenditure for Domestic Crawfish	lagnwcd
One Year Lagged Normalized Expenditure for Imported Crawfish	lagnwcm
One Year Lagged Normalized Expenditure for Catfish	lagnwca
One Year Lagged Normalized Expenditure for Shrimp	lagnwsh
One Year Lagged Normalized Expenditure for Oysters	lagnwoy
Moving Average in Normalized Expenditure for Domestic Crawfish	bwcd
Moving Average in Normalized Expenditure for Imported Crawfish	bwcm
Moving Average in Normalized Expenditure for Catfish	bwca
Moving Average in Normalized Expenditure for Shrimp	bwsh
Moving Average in Normalized Expenditure for Oysters	bwoy
One Year Lagged Moving Average in Normalized Expenditure for Domestic Crawfish	lagbwcd
One Year Lagged Moving Average in Normalized Expenditure for Imported Crawfish	lagbwcm
One Year Lagged Moving Average in Normalized Expenditure for Catfish	lagbwca
One Year Lagged Moving Average in Normalized Expenditure for Shrimp	lagbwsh
One Year Lagged Moving Average in Normalized Expenditure for Oysters	lagbwoy
DIAIDS Dependent Variable for Domestic Crawfish	dbwcd
DIAIDS Dependent Variable for Imported Crawfish	dbwcm

APPENDIX I. (Cont.)

Variables	Abbreviation
DIAIDS Dependent Variable for Catfish	dbwca
DIAIDS Dependent Variable for Shrimp	dbwsh
DIAIDS Dependent Variable for Oysters	dbwoy
Log Domestic Crawfish Price	lncrdp
Log Imported Crawfish Price	lncrmp
Log Domestic Catfish Price	lncadp
Log Domestic Shrimp Price	lnshdp
Log Domestic Oysters Price	lnoydp
One Year Lagged Log Domestic Crawfish Price	laglncrdp
One Year Lagged Log Imported Crawfish Price	laglncrmp
One Year Lagged Log Domestic Catfish Price	laglncadp
One Year Lagged Log Domestic Shrimp Price	laglnshdp
One Year Lagged Log Domestic Oysters Price	laglnoydp
Difference Log Domestic Crawfish Price	dlncrdp
Difference Log Imported Crawfish Price	dlncrmp
Difference Log Domestic Catfish Price	dlncadp
Difference Log Domestic Shrimp Price	dlnshdp
Difference Log Domestic Oysters Price	dlnoydp
Divisia Price Index	dlnP
Log Normalized Domestic Crawfish Supply	lnncrds
Log Normalized Imported Crawfish Suppy	lnncrms
Log Normalized Catfish Supply	lnncats

APPENDIX I. (Cont.)

Variables	Abbreviation
Log Normalized Shrimp Supply	lnnshts
Log Normalized Oysters Supply	lnnoyts
One Year Lagged Log Normalized Domestic Crawfish Supply	laglnncrds
One Year Lagged Log Normalized Imported Crawfish Supply	laglnncrms
One Year Lagged Log Normalized Catfish Supply	laglnncats
One Year Lagged Log Normalized Shrimp Supply	laglnnshts
One Year Lagged Log Normalized Oysters Supply	laglnnoyts
Difference Log Normalized Domestic Crawfish Supply	dlnncrds
Difference Log Normalized Imported Crawfish Supply	dlnncrms
Difference Log Normalized Catfish Supply	dlnncats
Difference Log Normalized Shrimp Supply	dlnnshts
Difference Log Normalized Oysters Supply	dlnnoyts
Quantity Divisia Index	dlnQ
Mixing Parameter θ_1 for Domestic Crawfish	bwcddlnQ
Mixing Parameter θ_1 for Imported Crawfish	bwcmdlnQ
Mixing Parameter θ_1 for Catfish	bwcadlnQ
Mixing Parameter θ_1 for Shrimp	bwshdlnQ
Mixing Parameter θ_1 for Oysters	bwoydlnQ
Mixing Parameter θ_2 for Domestic Crawfish	bwcddlnncrdsQ
Mixing Parameter θ_2 for Imported Crawfish	bwcmdlnncrmsQ
Mixing Parameter θ_2 for Catfish	bwcadlnncatsQ

APPENDIX I. (Cont.)

Variables	Abbreviation
Mixing Parameter θ_2 for Shrimp	bwshdlnnshtsQ
Mixing Parameter θ_2 for Oysters	bwoydlnnoytsQ
GIDS and DIRDS Dependent Variable for Domestic Crawfish	bwcddlnncrdp
GIDS and DIRDS Dependent Variable for Imported Crawfish	bwcmdlnncrmp
GIDS and DIRDS Dependent Variable for Catfish	bwcadlnncadp
GIDS and DIRDS Dependent Variable for Shrimp	bwshdlnnshdp
GIDS and DIRDS Dependent Variable for Oysters	bwoydlnnoydp
DICBS Dependent Variable for Domestic Crawfish	bwcddlncdP
DICBS Dependent Variable for Imported Crawfish	bwcmdlncmP
DICBS Dependent Variable for Catfish	bwcadlncaP
DICBS Dependent Variable for Shrimp	bwshdlnshP
DICBS Dependent Variable for Oysters	bwoydlnoyP
DINBR Dependent Variable for Domestic Crawfish	dbwcddlnQ
DINBR Dependent Variable for Imported Crawfish	dbwcmdlnQ
DINBR Dependent Variable for Catfish	dbwcadlnQ
DINBR Dependent Variable for Shrimp	dbwshdlnQ
DINBR Dependent Variable for Oysters	dbwoydlnQ

APPENDIX II. DATA USED IN THIS ANALYSIS

year	crds	crdp	crms	crmp	cats	cadp	shts	shdp	oyts	oydp
1980	346	13.79	0	-	27844	2.00	253565	4.42	13797	3.72
1981	278	12.50	0	-	31870	1.88	261871	4.53	17228	3.80
1982	416	12.82	0	-	47763	1.62	252917	5.89	19706	3.85
1983	761	11.80	0	-	64194	1.81	268118	6.44	18868	3.94
1984	747	12.58	0	-	72765	2.04	292227	5.83	20620	4.15
1985	974	11.24	0	-	90118	2.15	314610	5.17	24086	3.88
1986	1768	10.84	0	-	100662	1.97	363006	5.78	22960	3.77
1987	1991	7.76	0	-	130442	1.82	381674	6.00	21960	4.06
1988	1841	9.25	0	-	136510	2.26	378637	5.97	19115	4.83
1989	4367	9.54	3	2.85	158179	2.11	387585	5.61	14234	5.48
1990	2087	8.66	9	7.26	165316	2.24	384121	5.60	11376	5.77
1991	2296	7.58	33	7.44	179648	2.09	389943	6.08	9399	6.41
1992	3948	8.02	193	7.00	208786	2.00	423290	5.90	10173	6.73
1993	4500	7.18	281	6.95	210069	2.18	411865	6.32	13133	6.17
1994	2546	5.60	714	5.55	200830	2.39	413022	7.83	11669	6.08
1995	3670	5.20	1288	7.32	203804	2.40	410081	7.68	11289	6.51
1996	1390	7.25	1267	3.98	215277	2.36	407938	7.27	12321	6.85
1997	1641	7.80	1034	4.25	238540	2.26	433041	8.14	14491	6.93
1998	1678	8.42	2818	3.89	256616	2.31	459966	8.02	14427	6.18
1999	949	8.26	1762	3.79	272191	2.34	474996	7.85	14978	6.46
2000	121	15.72	2884	4.73	272990	2.38	495886	8.97	16687	7.00
2001	187	17.41	5859	8.19	279044	2.25	547514	7.66	14188	7.26
2002	572	12.79	4147	7.68	290663	2.07	585838	6.74	17205	6.52
2003	728	13.06	7101	8.66	302516	2.05	651535	6.45	19891	5.99
2004	677	13.11	6639	7.39	290151	2.24	661732	6.24	20458	7.02
2005	761	13.57	3956	5.07	286114	2.33	647767	6.25	18127	6.89

Soucers: National Marine Fisheries Service and USDA.

APPENDIX III. SAS CODE: GENERALIZED INVERSE DEMAND MODEL

Variable Description

```
wcd=crdp*crds;
wcm=crmp*crms;
wca=cadp*cats;
wsh=shdp*shts;
woy=oydp*oyts;

w=wcd+wcm+wca+wsh+woy;

ncrdp=(crdp*crds)/w;
ncrmp=(crmp*crms)/w;
ncadp=(cadp*cats)/w;
nshdp=(shdp*shts)/w;
noydp=(oydp*oyts)/w;

ncrds=crds/1586.15;
ncrms=crms/1538.00;
ncats=cats/177871.54;
nshts=shts/421259.42;
noyts=oyts/16245.62;

lnncrdp=log(ncrdp);
lnncrmp=log(ncrmp);
lnncadp=log(ncadp);
lnnshdp=log(nshdp);
lnnoydp=log(noydp);

laglnncrdp=lag(lnncrdp);
laglnncrmp=lag(lnncrmp);
laglnncadp=lag(lnncadp);
laglnnshdp=lag(lnnshdp);
laglnnoydp=lag(lnnoydp);

dlnncrdp=lnncrdp-laglnncrdp;
dlnncrmp=lnncrmp-laglnncrmp;
dlnncadp=lnncadp-laglnncadp;
dlnnshdp=lnnshdp-laglnnshdp;
dlnnoydp=lnnoydp-laglnnoydp;

nwcd=ncrdp*ncrds;
nwcm=ncrmp*ncrms;
nwca=ncadp*ncats;
nwsh=nshdp*nshts;
nwoy=noydp*noyts;

lagnwcd=lag(nwcd);
lagnwcm=lag(nwcm);
lagnwca=lag(nwca);
lagnwsh=lag(nwsh);
lagnwoy=lag(nwoy);

bwcd=(nwcd+lagnwcd)/2;
bwcm=(nwcm+lagnwcm)/2;
```

APPENDIX III. (Cont.)

```
bwca=(nwca+lagnwca)/2;
bwsh=(nwsh+lagnwsh)/2;
bwoy=(nwoy+lagnwoy)/2;

lagbwcd=lag(bwcd);
lagbwcm=lag(bwcm);
lagbwca=lag(bwca);
lagbwsh=lag(bwsh);
lagbwoy=lag(bwoy);

dbwcd=bwcd-lagbwcd;
dbwcm=bwcm-lagbwcm;
dbwca=bwca-lagbwca;
dbwsh=bwsh-lagbwsh;
dbwoy=bwoy-lagbwoy;

lncrdp=log(crdp);
lncrmp=log(crmp);
lncadp=log(cadp);
lnshdp=log(shdp);
lnoydp=log(oydp);

laglncrdp=lag(lncrdp);
laglncrmp=lag(lncrmp);
laglncadp=lag(lncadp);
laglnshdp=lag(lnshdp);
laglnoydp=lag(lnoydp);

dlncrdp=lncrdp-laglncrdp;
dlncrmp=lncrmp-laglncrmp;
dlncadp=lncadp-laglncadp;
dlnshdp=lnshdp-laglnshdp;
dlnoydp=lnoydp-laglnoydp;

dlnP=bwcd*dlncrdp+bwcm*dlncrmp+bwca*dlncadp+bwsh*dlnshdp+bwoy*dlnoydp;

lnncrds=log(ncrds);
lnncrms=log(ncrms);
lnncats=log(ncats);
lnnshts=log(nshts);
lnnoyts=log(noyts);

laglnncrds=lag(lnncrds);
laglnncrms=lag(lnncrms);
laglnncats=lag(lnncats);
laglnnshts=lag(lnnshts);
laglnnoyts=lag(lnnoyts);

dlnncrds=lnncrds-laglnncrds;
dlnncrms=lnncrms-laglnncrms;
dlnncats=lnncats-laglnncats;
dlnnshts=lnnshts-laglnnshts;
dlnnoyts=lnnoyts-laglnnoyts;
```

```
dlnQ=bwcd*dlnncrds+bwcm*dlnncrms+bwca*dlnncats+bwsh*dlnnshts+
     bwoy*dlnnoyts;

bwcddlnQ=bwcd*dlnQ;
bwcmdlnQ=bwcm*dlnQ;
bwcadlnQ=bwca*dlnQ;
bwshdlnQ=bwsh*dlnQ;
bwoydlnQ=bwoy*dlnQ;

bwcddlnncrdsQ=bwcd*(dlnncrds-dlnQ);
bwcmdlnncrmsQ=bwcm*(dlnncrms-dlnQ);
bwcadlnncatsQ=bwca*(dlnncats-dlnQ);
bwshdlnnshtsQ=bwsh*(dlnnshts-dlnQ);
bwoydlnnoytsQ=bwoy*(dlnnoyts-dlnQ);

bwcddlnncrdp=bwcd*dlnncrdp;
bwcmdlnncrmp=bwcm*dlnncrmp;
bwcadlnncadp=bwca*dlnncadp;
bwshdlnnshdp=bwsh*dlnnshdp;
bwoydlnnoydp=bwoy*dlnnoydp;

bwcddlncdP=bwcd*(dlncrdp-dlnP);
bwcmdlncmP=bwcm*(dlncrmp-dlnP);
bwcadlncaP=bwca*(dlncadp-dlnP);
bwshdlnshP=bwsh*(dlnshdp-dlnP);
bwoydlnoyP=bwoy*(dlnoydp-dlnP);

dbwcddlnQ=dbwcd-bwcd*dlnQ;
dbwcmdlnQ=dbwcm-bwcm*dlnQ;
dbwcadlnQ=dbwca-bwca*dlnQ;
dbwshdlnQ=dbwsh-bwsh*dlnQ;
dbwoydlnQ=dbwoy-bwoy*dlnQ;
```

Generalized Inverse Demand System (GIDS)

```
proc syslin data=crawfish sur vardef=n out=ehatdat1;
domestic:model bwcddlnncrdp=dlnncrds dlnncrms dlnncats dlnnshts
                          dlnnoyts dlnQ bwcddlnQ bwcddlnncrdsQ/dw;
imports:model  bwcmdlnncrmp=dlnncrds dlnncrms dlnncats dlnnshts
                          dlnnoyts dlnQ bwcmdlnQ bwcmdlnncrmsQ/dw;
catfish:model  bwcadlnncadp=dlnncrds dlnncrms dlnncats dlnnshts
                          dlnnoyts dlnQ bwcadlnQ bwcadlnncatsQ/dw;
shrimp:model   bwshdlnnshdp=dlnncrds dlnncrms dlnncats dlnnshts
                          dlnnoyts dlnQ bwshdlnQ bwshdlnnshtsQ/dw;
oysters:model  bwoydlnnoydp=dlnncrds dlnncrms dlnncats dlnnshts
                          dlnnoyts dlnQ bwoydlnQ bwoydlnnoytsQ/dw;
srestrict
domestic.bwcddlnQ=imports.bwcmdlnQ=catfish.bwcadlnQ=shrimp.bwshdlnQ=oys
ters.bwoydlnQ,

domestic.bwcddlnncrdsQ=imports.bwcmdlnncrmsQ=catfish.bwcadlnncatsQ=shri
mp.bwshdlnnshtsQ=oysters.bwoydlnnoytsQ,
```

APPENDIX III. (Cont.)

```
domestic.dlnQ+imports.dlnQ+catfish.dlnQ+shrimp.dlnQ+oysters.dlnQ=-1,

domestic.dlnncrds+imports.dlnncrds+catfish.dlnncrds+shrimp.dlnncrds+oys
ters.dlnncrds=0,

domestic.dlnncrms+imports.dlnncrms+catfish.dlnncrms+shrimp.dlnncrms+oys
ters.dlnncrms=0,

domestic.dlnncats+imports.dlnncats+catfish.dlnncats+shrimp.dlnncats+oys
ters.dlnncats=0,

domestic.dlnnshts+imports.dlnnshts+catfish.dlnnshts+shrimp.dlnnshts+oys
ters.dlnnshts=0,

domestic.dlnnoyts+imports.dlnnoyts+catfish.dlnnoyts+shrimp.dlnnoyts+oys
ters.dlnnoyts=0,

domestic.intercept+imports.intercept+catfish.intercept+shrimp.intercept
+oysters.intercept=0,

domestic.dlnncrds+domestic.dlnncrms+domestic.dlnncats+domestic.dlnnshts
+domestic.dlnnoyts=0,

imports.dlnncrds+imports.dlnncrms+imports.dlnncats+imports.dlnnshts+imp
orts.dlnnoyts=0,

catfish.dlnncrds+catfish.dlnncrms+catfish.dlnncats+catfish.dlnnshts+cat
fish.dlnnoyts=0,

shrimp.dlnncrds+shrimp.dlnncrms+shrimp.dlnncats+shrimp.dlnnshts+shrimp.
dlnnoyts=0,

oysters.dlnncrds+oysters.dlnncrms+oysters.dlnncats+oysters.dlnnshts+oys
ters.dlnnoyts=0,

domestic.dlnncrms=imports.dlnncrds, domestic.dlnncats=catfish.dlnncrds,
domestic.dlnnshts=shrimp.dlnncrds, domestic.dlnnoyts=oysters.dlnncrds,
imports.dlnncats=catfish.dlnncrms, imports.dlnnshts=shrimp.dlnncrms,
imports.dlnnoyts=oysters.dlnncrms,
catfish.dlnnshts=shrimp.dlnncats, catfish.dlnnoyts=oysters.dlnncats,
shrimp.dlnnoyts=oysters.dlnnshts;

stest domestic.bwcddlnQ=1;
stest domestic.bwcddlnQ=0;
stest domestic.bwcddlnncrdsQ=1;
stest domestic.bwcddlnncrdsQ=0;
stest domestic.bwcddlnQ=0, domestic.bwcddlnncrdsQ=0;
stest domestic.bwcddlnQ=1, domestic.bwcddlnncrdsQ=1;
stest domestic.bwcddlnQ=0, domestic.bwcddlnncrdsQ=1;
stest domestic.bwcddlnQ=1, domestic.bwcddlnncrdsQ=0;
output r=ehat;
```

APPENDIX III. (Cont.)

```
data rhohat1;
set ehatdat1;
ehat1=lag(ehat);

proc reg;
rhohat1:model ehat=ehat1/noint;
```

APPENDIX IV. SAS CODE:
DIFFERENTIAL INVERSE ROTTERDAM DEMAND MODEL

```
proc syslin data=crawfish sur vardef=n out=ehatdat2;
domestic:model bwcddlnncrdp=dlnncrds dlnncrms dlnncats dlnnshts
                            dlnnoyts dlnQ/dw;
imports:model  bwcmdlnncrmp=dlnncrds dlnncrms dlnncats dlnnshts
                            dlnnoyts dlnQ/dw;
catfish:model  bwcadlnncadp=dlnncrds dlnncrms dlnncats dlnnshts
                            dlnnoyts dlnQ/dw;
shrimp:model   bwshdlnnshdp=dlnncrds dlnncrms dlnncats dlnnshts
                            dlnnoyts dlnQ/dw;
oysters:model  bwoydlnnoydp=dlnncrds dlnncrms dlnncats dlnnshts
                            dlnnoyts dlnQ/dw;
srestrict
domestic.dlnQ+imports.dlnQ+catfish.dlnQ+shrimp.dlnQ+oysters.dlnQ=-1,

domestic.dlnncrds+imports.dlnncrds+catfish.dlnncrds+shrimp.dlnncrds+oys
ters.dlnncrds=0,

domestic.dlnncrms+imports.dlnncrms+catfish.dlnncrms+shrimp.dlnncrms+oys
ters.dlnncrms=0,

domestic.dlnncats+imports.dlnncats+catfish.dlnncats+shrimp.dlnncats+oys
ters.dlnncats=0,

domestic.dlnnshts+imports.dlnnshts+catfish.dlnnshts+shrimp.dlnnshts+oys
ters.dlnnshts=0,

domestic.dlnnoyts+imports.dlnnoyts+catfish.dlnnoyts+shrimp.dlnnoyts+oys
ters.dlnnoyts=0,

domestic.intercept+imports.intercept+catfish.intercept+shrimp.intercept
+oysters.intercept=0,

domestic.dlnncrds+domestic.dlnncrms+domestic.dlnncats+domestic.dlnnshts
+domestic.dlnnoyts=0,

imports.dlnncrds+imports.dlnncrms+imports.dlnncats+imports.dlnnshts+imp
orts.dlnnoyts=0,

catfish.dlnncrds+catfish.dlnncrms+catfish.dlnncats+catfish.dlnnshts+cat
fish.dlnnoyts=0,

shrimp.dlnncrds+shrimp.dlnncrms+shrimp.dlnncats+shrimp.dlnnshts+shrimp.
dlnnoyts=0,

oysters.dlnncrds+oysters.dlnncrms+oysters.dlnncats+oysters.dlnnshts+oys
ters.dlnnoyts=0,
domestic.dlnncrms=imports.dlnncrds, domestic.dlnncats=catfish.dlnncrds,
domestic.dlnnshts=shrimp.dlnncrds, domestic.dlnnoyts=oysters.dlnncrds,
imports.dlnncats=catfish.dlnncrms, imports.dlnnshts=shrimp.dlnncrms,
imports.dlnnoyts=oysters.dlnncrms,
catfish.dlnnshts=shrimp.dlnncats, catfish.dlnnoyts=oysters.dlnncats,
shrimp.dlnnoyts=oysters.dlnnshts;
```

APPENDIX IV. (Cont.)

```
output r=ehat;

data rhohat2;
set ehatdat2;
ehat1=lag(ehat);

proc reg;
rhohat2:model ehat=ehat1/noint;
```

APPEMDIX V. SAS CODE:
DIFFERENTIAL INVERSE ALMOST IDEAL DEMAND MODEL

```
proc syslin data=crawfish sur vardef=n out=ehatdat3;
domestic:model dbwcd=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                     dlnQ/dw;
imports:model  dbwcm=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                     dlnQ/dw;
catfish:model  dbwca=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                     dlnQ/dw;
shrimp:model   dbwsh=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                     dlnQ/dw;
oysters:model  dbwoy=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                     dlnQ/dw;
srestrict
domestic.dlnQ+imports.dlnQ+catfish.dlnQ+shrimp.dlnQ+oysters.dlnQ=0,

domestic.dlnncrds+imports.dlnncrds+catfish.dlnncrds+shrimp.dlnncrds+oys
ters.dlnncrds=0,

domestic.dlnncrms+imports.dlnncrms+catfish.dlnncrms+shrimp.dlnncrms+oys
ters.dlnncrms=0,

domestic.dlnncats+imports.dlnncats+catfish.dlnncats+shrimp.dlnncats+oys
ters.dlnncats=0,

domestic.dlnnshts+imports.dlnnshts+catfish.dlnnshts+shrimp.dlnnshts+oys
ters.dlnnshts=0,

domestic.dlnnoyts+imports.dlnnoyts+catfish.dlnnoyts+shrimp.dlnnoyts+oys
ters.dlnnoyts=0,

domestic.intercept+imports.intercept+catfish.intercept+shrimp.intercept
+oysters.intercept=0,

domestic.dlnncrds+domestic.dlnncrms+domestic.dlnncats+domestic.dlnnshts
+domestic.dlnnoyts=0,

imports.dlnncrds+imports.dlnncrms+imports.dlnncats+imports.dlnnshts+imp
orts.dlnnoyts=0,

catfish.dlnncrds+catfish.dlnncrms+catfish.dlnncats+catfish.dlnnshts+cat
fish.dlnnoyts=0,

shrimp.dlnncrds+shrimp.dlnncrms+shrimp.dlnncats+shrimp.dlnnshts+shrimp.
dlnnoyts=0,

oysters.dlnncrds+oysters.dlnncrms+oysters.dlnncats+oysters.dlnnshts+oys
ters.dlnnoyts=0,

domestic.dlnncrms=imports.dlnncrds, domestic.dlnncats=catfish.dlnncrds,
domestic.dlnnshts=shrimp.dlnncrds, domestic.dlnnoyts=oysters.dlnncrds,
imports.dlnncats=catfish.dlnncrms, imports.dlnnshts=shrimp.dlnncrms,
imports.dlnnoyts=oysters.dlnncrms,
catfish.dlnnshts=shrimp.dlnncats, catfish.dlnnoyts=oysters.dlnncats,
shrimp.dlnnoyts=oysters.dlnnshts;
```

APPENDIX V. (Cont.)

```
output r=ehat;

data rhohat3;
set ehatdat3;
ehat1=lag(ehat);

proc reg;
rhohat3:model ehat=ehat1/noint;
```

APPENDIX VI. SAS CODE: DIFFERENTIAL INVERSE CBS MODEL

```
proc syslin data=crawfish sur vardef=n out=ehatdat4;
domestic:model bwcddlncdP=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                          dlnQ/dw;
imports:model  bwcmdlncmP=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                          dlnQ/dw;
catfish:model  bwcadlncaP=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                          dlnQ/dw;
shrimp:model   bwshdlnshP=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                          dlnQ/dw;
oysters:model  bwoydlnoyP=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                          dlnQ/dw;
srestrict
domestic.dlnQ+imports.dlnQ+catfish.dlnQ+shrimp.dlnQ+oysters.dlnQ=0,

domestic.dlnncrds+imports.dlnncrds+catfish.dlnncrds+shrimp.dlnncrds+oys
ters.dlnncrds=0,

domestic.dlnncrms+imports.dlnncrms+catfish.dlnncrms+shrimp.dlnncrms+oys
ters.dlnncrms=0,

domestic.dlnncats+imports.dlnncats+catfish.dlnncats+shrimp.dlnncats+oys
ters.dlnncats=0,

domestic.dlnnshts+imports.dlnnshts+catfish.dlnnshts+shrimp.dlnnshts+oys
ters.dlnnshts=0,

domestic.dlnnoyts+imports.dlnnoyts+catfish.dlnnoyts+shrimp.dlnnoyts+oys
ters.dlnnoyts=0,

domestic.intercept+imports.intercept+catfish.intercept+shrimp.intercept
+oysters.intercept=0,

domestic.dlnncrds+domestic.dlnncrms+domestic.dlnncats+domestic.dlnnshts
+domestic.dlnnoyts=0,

imports.dlnncrds+imports.dlnncrms+imports.dlnncats+imports.dlnnshts+imp
orts.dlnnoyts=0,

catfish.dlnncrds+catfish.dlnncrms+catfish.dlnncats+catfish.dlnnshts+cat
fish.dlnnoyts=0,

shrimp.dlnncrds+shrimp.dlnncrms+shrimp.dlnncats+shrimp.dlnnshts+shrimp.
dlnnoyts=0,

oysters.dlnncrds+oysters.dlnncrms+oysters.dlnncats+oysters.dlnnshts+oys
ters.dlnnoyts=0,

domestic.dlnncrms=imports.dlnncrds, domestic.dlnncats=catfish.dlnncrds,
domestic.dlnnshts=shrimp.dlnncrds, domestic.dlnnoyts=oysters.dlnncrds,
imports.dlnncats=catfish.dlnncrms, imports.dlnnshts=shrimp.dlnncrms,
imports.dlnnoyts=oysters.dlnncrms,
catfish.dlnnshts=shrimp.dlnncats, catfish.dlnnoyts=oysters.dlnncats,
shrimp.dlnnoyts=oysters.dlnnshts;
```

APPENDIX VI. (Cont.)

```
output r=ehat;

data rhohat4;
set ehatdat4;
ehat1=lag(ehat);

proc reg;
rhohat4:model ehat=ehat1/noint;
```

APPENDIX VII. SAS CODE: DIFFERENTIAL INVERSE NBR MODEL

```
proc syslin data=crawfish sur vardef=n out=ehatdat5;
domestic:model dbwcddlnQ=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                         dlnQ/dw;
imports:model  dbwcmdlnQ=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                         dlnQ/dw;
catfish:model  dbwcadlnQ=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                         dlnQ/dw;
shrimp:model   dbwshdlnQ=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                         dlnQ/dw;
oysters:model  dbwoydlnQ=dlnncrds dlnncrms dlnncats dlnnshts dlnnoyts
                         dlnQ/dw;
srestrict
domestic.dlnQ+imports.dlnQ+catfish.dlnQ+shrimp.dlnQ+oysters.dlnQ=0,

domestic.dlnncrds+imports.dlnncrds+catfish.dlnncrds+shrimp.dlnncrds+oys
ters.dlnncrds=0,

domestic.dlnncrms+imports.dlnncrms+catfish.dlnncrms+shrimp.dlnncrms+oys
ters.dlnncrms=0,

domestic.dlnncats+imports.dlnncats+catfish.dlnncats+shrimp.dlnncats+oys
ters.dlnncats=0,

domestic.dlnnshts+imports.dlnnshts+catfish.dlnnshts+shrimp.dlnnshts+oys
ters.dlnnshts=0,

domestic.dlnnoyts+imports.dlnnoyts+catfish.dlnnoyts+shrimp.dlnnoyts+oys
ters.dlnnoyts=0,

domestic.intercept+imports.intercept+catfish.intercept+shrimp.intercept
+oysters.intercept=0,

domestic.dlnncrds+domestic.dlnncrms+domestic.dlnncats+domestic.dlnnshts
+domestic.dlnnoyts=0,

imports.dlnncrds+imports.dlnncrms+imports.dlnncats+imports.dlnnshts+imp
orts.dlnnoyts=0,

catfish.dlnncrds+catfish.dlnncrms+catfish.dlnncats+catfish.dlnnshts+cat
fish.dlnnoyts=0,

shrimp.dlnncrds+shrimp.dlnncrms+shrimp.dlnncats+shrimp.dlnnshts+shrimp.
dlnnoyts=0,

oysters.dlnncrds+oysters.dlnncrms+oysters.dlnncats+oysters.dlnnshts+oys
ters.dlnnoyts=0,

domestic.dlnncrms=imports.dlnncrds, domestic.dlnncats=catfish.dlnncrds,
domestic.dlnnshts=shrimp.dlnncrds, domestic.dlnnoyts=oysters.dlnncrds,
imports.dlnncats=catfish.dlnncrms, imports.dlnnshts=shrimp.dlnncrms,
imports.dlnnoyts=oysters.dlnncrms,
catfish.dlnnshts=shrimp.dlnncats, catfish.dlnnoyts=oysters.dlnncats,
                  shrimp.dlnnoyts=oysters.dlnnshts;
```

```
output r=ehat;

data rhohat5;
set ehatdat5;
ehat1=lag(ehat);

proc reg;
rhohat5:model ehat=ehat1/noint;
```

VITA

YOUNG-JAE LEE was born on August 11, 1963, in Choong-Chung-Book-Do, South Korea. He graduated from Kyung-Hee University, Seoul, Korea, in February 1987, for a bachelor's degree, and February 1989, for a master's degree, where he received the title of Bachelor and Master of Science in Agriculture, respectively. After the completion of these degrees he worked for National Agricultural Cooperative Federation as a manager until 2001. In August, 2001, he enrolled in the graduate school at University of Arkansas, where he obtained the degree of Master of Science in Agricultural Economics in December, 2003. In August, 2003, he entered the doctoral program in the Department of Agricultural Economics and Agribusiness at Louisiana State University, and currently he is a candidate for the degree of Doctor of Philosophy.