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An Analysis of the World Shrimp Market and the Impact of an Increasing Import Base on the Gulf of Mexico Dockside Price

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AN ANALYSIS OF THE WORLD SHRIMP MARKET AND THE IMPACT OF AN INCREASING IMPORT BASE ON THE GULF OF MEXICO DOCKSIDE PRICE

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ABSTRACT

As a result of increased cultured activities, the world shrimp market has been expanded significantly during the past two decades. Because the growth in world supply has exceeded that of growth in demand, the deflated world shrimp price has fallen significantly since the mid-1980s. While a large producer of shrimp (primarily in the Gulf of Mexico), the United States is also the world's largest importer. In general, the Gulf of Mexico dockside price is determined by the world export price and, as such, the Gulf of Mexico price has fallen sharply in recent years. This study quantifies the impact on the U.S. Gulf of Mexico dockside shrimp price associated with increased cultured shrimp activities and concomitant increased exports to the U.S. market.

For purposes of analysis, a set of import demand and export supply equations were estimated. Specifically, import demand equations were estimated for three countries (regions) that account for the majority of shrimp imports – the United States, Japan, and the European Union. Similarly, export supply equations, were developed for the three primary warm-water shrimp producing regions – Asia, South America, and Central America. Finally, an inverse demand equation associated with U.S. Gulf of Mexico shrimp production was estimated.

Results suggest that the increased cultured production from the three regions has had a significant impact on the Gulf of Mexico dockside price. For example, results indicate that the Gulf of Mexico dockside price is expected to decline by approximately 3.5% for every 10% increase in Asian production of cultured shrimp. Similarly, analysis suggests that the estimated decline in dockside price associated with a 10% increase in South American cultured shrimp production is 2.2%. While an increase in Central

American cultured shrimp production was also found to significantly reduce the dockside price, increases in captured shrimp production were found to have a greater impact.

CHAPTER I

INTRODUCTION

World shrimp exports, valued at around $12 billion, constitute nearly 17% of the $71 billion global seafood export market, in 2004 (FAO). The export market has expanded significantly since the early-to-mid 1980s and this expansion is primarily attributed to increased production. This increased production, in turn, is the result of an increase in the cultured production of shrimp; particularly in Asia and South America. As a result of this increased production, the traded volume increased from approximately 900 million pounds (product weight) in 1980 to nearly 4.6 billion pounds in 2004 and the export price, expressed in real terms (1982-84 U.S. CPI equal to the base), declined from $3.22 per product-weight pound in 1980 to $1.38 per pound in 2004.

The U.S. produces approximately 200 million pounds (headless shell-on weight) of shrimp annually. Most of this production occurs in the South Atlantic and Gulf regions of the United States which include the coastal states extending from North Carolina through Texas. In general, the capture shrimp fisheries throughout the United States are believed to be fully capitalized and annual variations in production can be attributed primarily to changes in environmental conditions that alter populations rather than changes in effort.

While a major producer of shrimp, the U.S is also the world's largest importer of shrimp. As world production of shrimp has expanded, export of this product to the United States has increased significantly. In 1985, for example, U.S. shrimp production equaled 207 million pounds (headless shell-on weight) while exports to the U.S. market totaled 452 million pounds (headless shell-on equivalent weight) (U.S. Dept. of

Commerce, 1992). By 2004, exports of shrimp to the U.S. market had increased to 1.5 billion pounds (headless shell-on equivalent weight) compared to domestic production of 193 million pounds (headless shell-on weight) (US Dept of Commerce, 2005). As a result of the rapid increase in U.S. shrimp imports, the price of the domestically harvested shrimp, when examined on a deflated basis, has fallen sharply.

In an attempt to limit imports, Gulf and South Atlantic shrimp producers petitioned the United States International Trade Commission (USITC) in 1985 requesting relief from the increasing imports and the impact of these increased imports on domestic dockside prices. In explaining the situation to the USITC, the Southeast U.S. shrimp harvesters claimed (a) that harvesting businesses were being injured as a result of imports, and (b) that shrimp industries in foreign countries were benefiting from government assistance which was artificially allowing their product to be more competitive in the U.S. market (United States International Trade Commission, 1985). Following a staff review of the information and a public hearing, the USITC chose only to issue a report rather than to recommend any remedies

With a significant increase in shrimp imports since 1985 and a further erosion in the dockside price, the Southern Shrimp Alliance, a coalition of shrimp producers in eight Southern States, filed a petition with the U.S. Department of Commerce at the end of 2003.[1] The petition alleged that six countries – Brazil, Ecuador, India, Thailand, Vietnam, and China- were 'dumping' excess production in the U.S. market in order to increase their respective shares. After an initial finding of dumping by the U.S.

[1] More accurately, the petition was filed by the Ad Hoc Shrimp Trade Action Committee, the Versaggi Shrimp Corporation, and the Indian Ridge Shrimp Company.

Department of Commerce, the U.S. International Trade Commission confirmed that dumping was occurring and set duties accordingly.[2]

While there is little doubt that increased production of cultured shrimp throughout Asia, South America, and Central America and the subsequent placement of this product in the international trade market has negatively impacted the U.S. domestic dockside price, attempts to quantify the impact have been limited. The overall goal of this thesis is to contribute to the limited body of literature on the subject. To do so, this chapter first presents some basic trends in terms of world shrimp production, trade, and the U.S. market. Then, a formal problem statement and specific objectives are presented. Chapter 2 presents a brief literature review of alternative trade models and develops the system of equations that are used in the current analysis. Results of the analysis are presented in Chapter 3. Finally, a brief summary of major findings along with a discussion of additional research to further our knowledge of the world shrimp market are presented in the last Chapter of this thesis

1.1 Trends in World Shrimp Production

World shrimp production, as indicated in Figure 1.1, has been increasing on a relatively steady basis since 1980. According to FAO fish stat data, annual shrimp production advanced from about 3.4 billion pounds (live-weight basis) in 1980 to 11.7 billion pounds in 2004, a nearly three and a half fold increase.

Shrimp production, like many other fishery products, represents a combination of captured and cultured product. Historically captured product was the dominant source of

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[2] Details of this petition, including a chronology of events leading the USITC's findings, can be found in *Certain Frozen or Canned Warmwater Shrimp and Pawn From Brazil, China, Equador, India, Thailand, and Vietnam* (United States International Trade Commission , 2005).

world output, but the share of total output represented by cultured production has been steadily increasing (Figure 1.2). In the early-to-mid 1980s, for example, cultured shrimp represented only about five percent of the total world production.

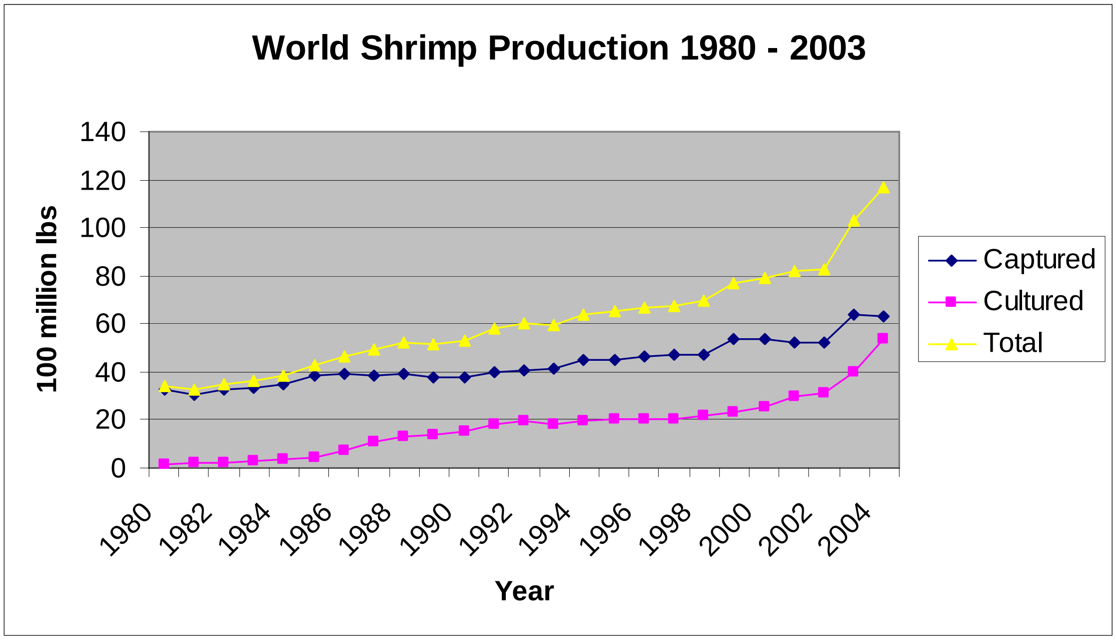

Figure 1.1: World Shrimp Production, Million pounds (Product Weight)

Beginning in the mid-1980s, the share of total output represented by cultured shrimp began to increase significantly and the share has consistently been above the 30% mark since the early 1990s. In 2004, cultured production was 5.3 billion pounds (live weight) which represented 46% of total world shrimp output. Overall, shrimp culture practices have expanded rapidly throughout the world, particularly in Asia and to a lesser extent in Central and South America.

1.2 Major Shrimp Producers

Three regions - Asia, Central America (which also includes the Caribbean islands) and South America – account for virtually all of the warm-water shrimp produced throughout the world. The combined output of these regions has consistently represented about 80% of total world output since 1980 with the remaining 20% of output representing cold-water shrimp.

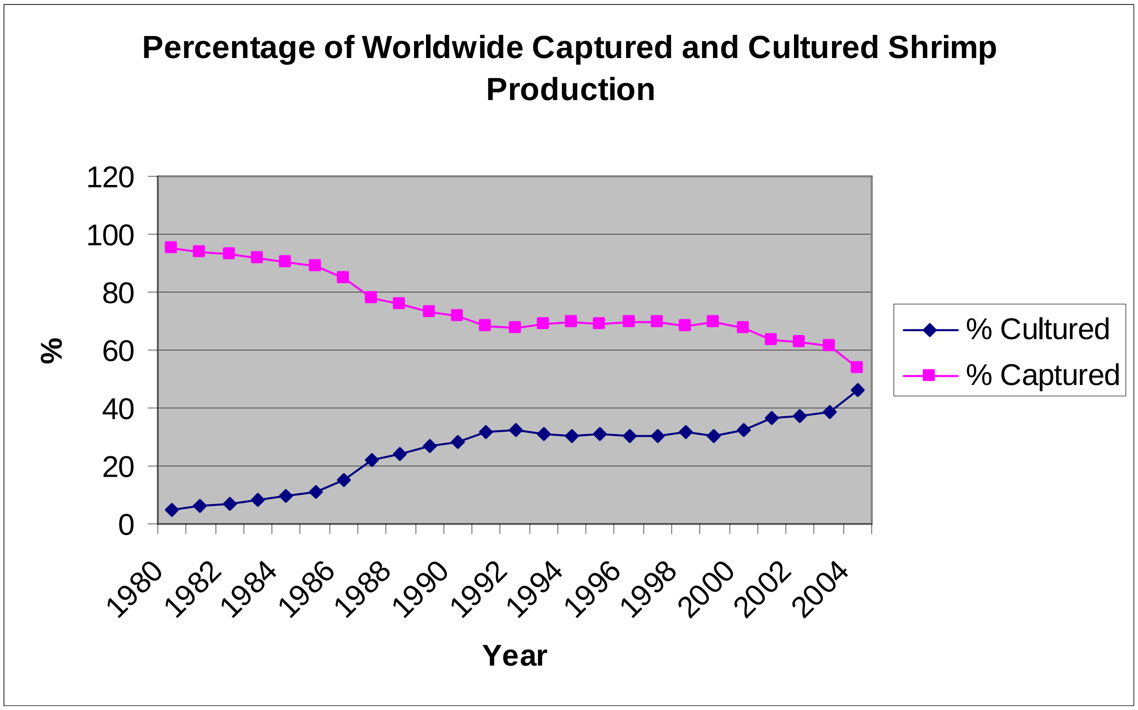

Figure 1.2: Percentage of Captured and Cultured World Shrimp Production

1.2.1 Asia

When examined by region, Asia is by far the world's largest producer of shrimp. Since 1980, more than 50% of the world shrimp production has come from Asia and the share of world output represented by Asia has exceeded 60% since 1990. In 2004, Asia's production totaled 8.87 billion pounds (live weight) of which more than four billion pounds represented a cultured product (Figure 1.3).

Seven of the 10 world's largest shrimp producers in 2003 were Asian countries. These seven producers - China, India, Indonesia, Thailand, Vietnam, Malaysia and The Philippines –had a combined output of 6.96 billion pounds which represented two-thirds of world production.

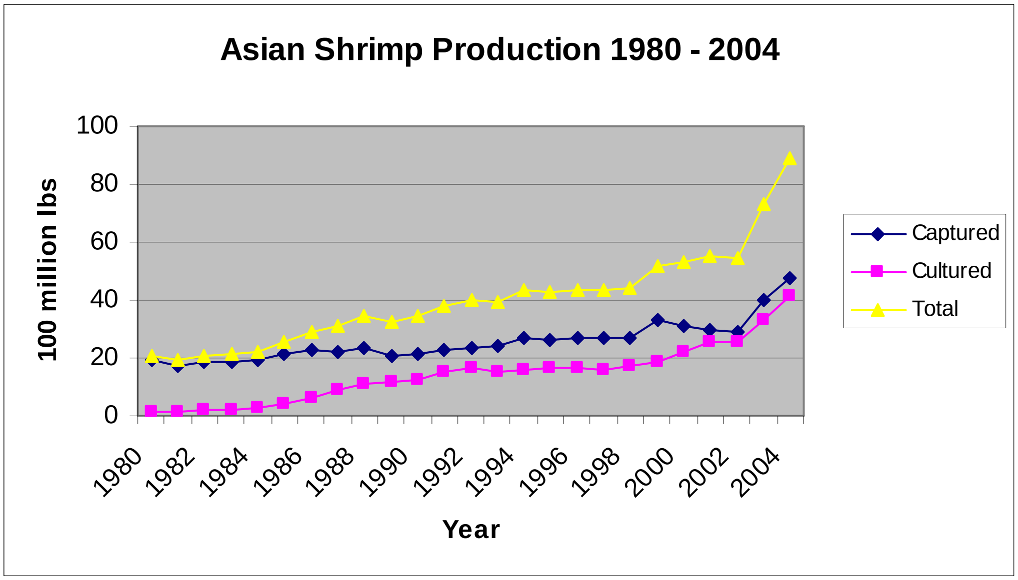

Figure 1.3: Asian Shrimp Production (Captured, Cultured and Total) 1980 – 2004

China, Indonesia, India, Thailand and Malaysia have traditionally been the largest Asian producers. China produced 2.9 billion pounds of shrimp in 2003, followed by 3.8 billion pounds in 2004. Similarly India produced close to 1.1 billion pounds in both 2003 and 2004. Since the early 1990s, Vietnamese shrimp production has been on the rise and Vietnam is currently one of the major producers in the world. As noted, four of these Asian countries – China, India, Thailand, and Vietnam – were targets of the recent dumping petition filed by the Southern Shrimp Alliance.

1.2.2 Central America

In total, production of shrimp in Central America increased from about 250 million pounds (live weight) annually in the 1980s to more than 400 million pounds in 2004. As indicated (Figure 1.4), all long-term growth in output in the region is the result of increased cultured production.

Mexico is the largest shrimp producer in the Central American region. It is also one of the top ten shrimp producing countries of the world. The total output of Mexico was approximately 270 million pounds (live weight) in both 2003 and 2004. Other major producers in this region include Honduras, Panama, Nicaragua and Guatemala. None of the Central American producers were listed in the dumping investigation that was initiated by the Southern Shrimp Alliance at the end of 2003.

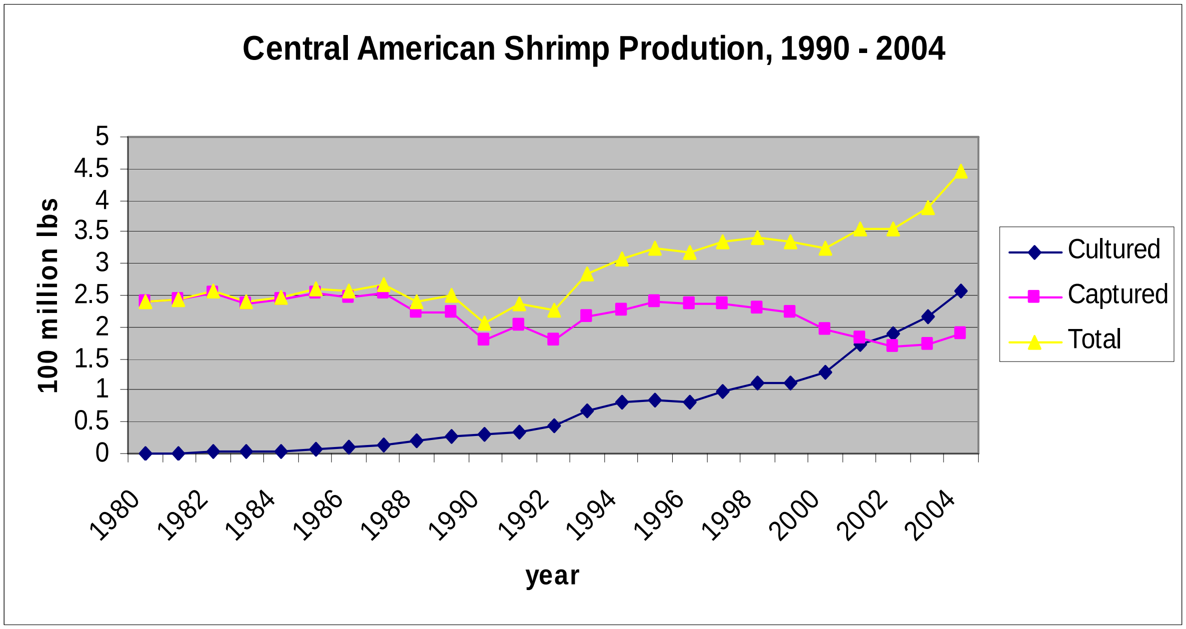

Figure 1.4: Central American Shrimp Production

1.2.3 South America

As indicated in Figure 5, South American shrimp production advanced from approximately 200 million pounds (live weight) in 1980 to more than 800 million pounds in 2004. Cultured production equaled about 379 million pounds in 2004 compared to only 20 million pounds in 1980 (Figure 1.5).

Brazil and Ecuador are the two major warm-water shrimp producers in the South American region (Argentina also produces a large amount of shrimp but most of its production is cold-water species). Brazil produced almost 260 million pounds of shrimp in 2003, followed by Ecuador with 131 million pounds and Argentina with 117 million pounds. Other producers in this region include Venezuela, Guyana, Colombia and Surinam. Both Brazil and Ecuador were listed in the 2003 dumping petition.

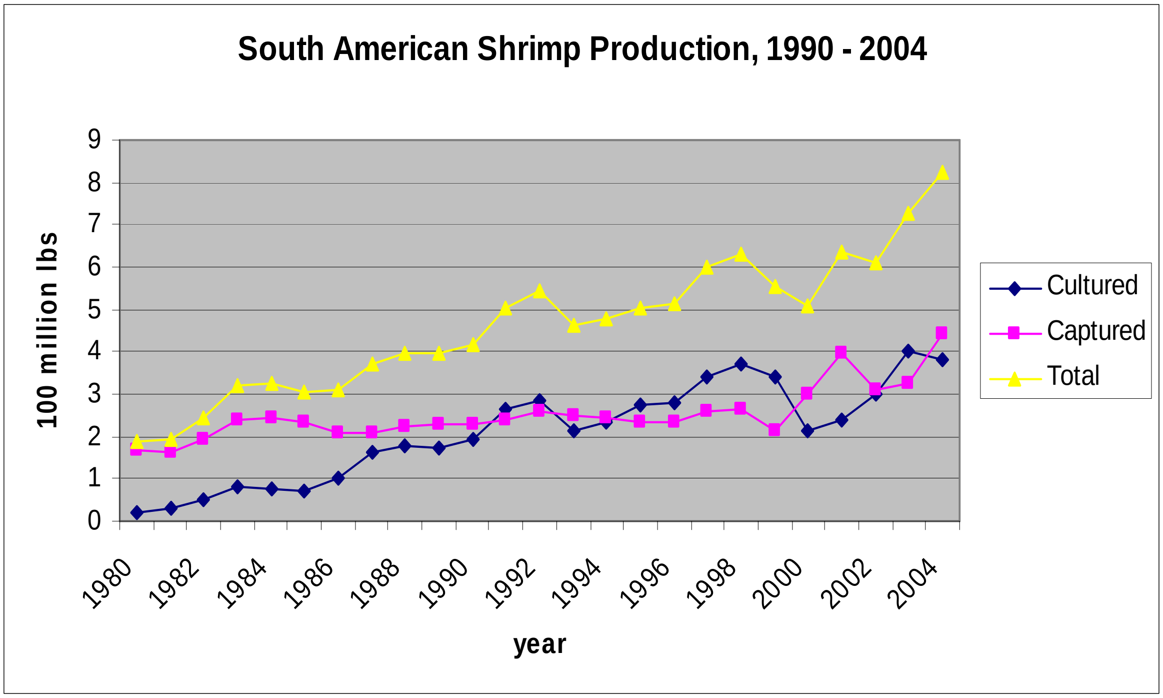

Figure 1.5: South American Shrimp Production

1.3 World Shrimp Trade

Shrimp is a major part of total fisheries product trade in the world. It was the largest fishery commodity traded in 2003 in terms of value, accounting for almost 18% of the total trade in seafood commodities, by value.

1.3.1 Exports

In conjunction with the increase in world shrimp production, exports of shrimp have significantly increased. In 1980, for example, world exports of shrimp equaled 900 million pounds (product weight). By 2004, it had more than quadrupled to four billion pounds (Figure 1.6).

A significant proportion of world shrimp production is traded in the world market. Comparison of total production and total trade volume gives a fairly good, though somewhat imprecise, estimate of the proportion of world production entering the trade market.[3] Total world production in 2004 equaled 10.3 billion pounds, expressed on a live weight basis. This is equivalent to approximately 6.8 billion pounds, expressed on a headless shell-on weigh basis. Compared to 4 billion pounds of total exports (product weight), this would imply that about 60% of total world production is traded.

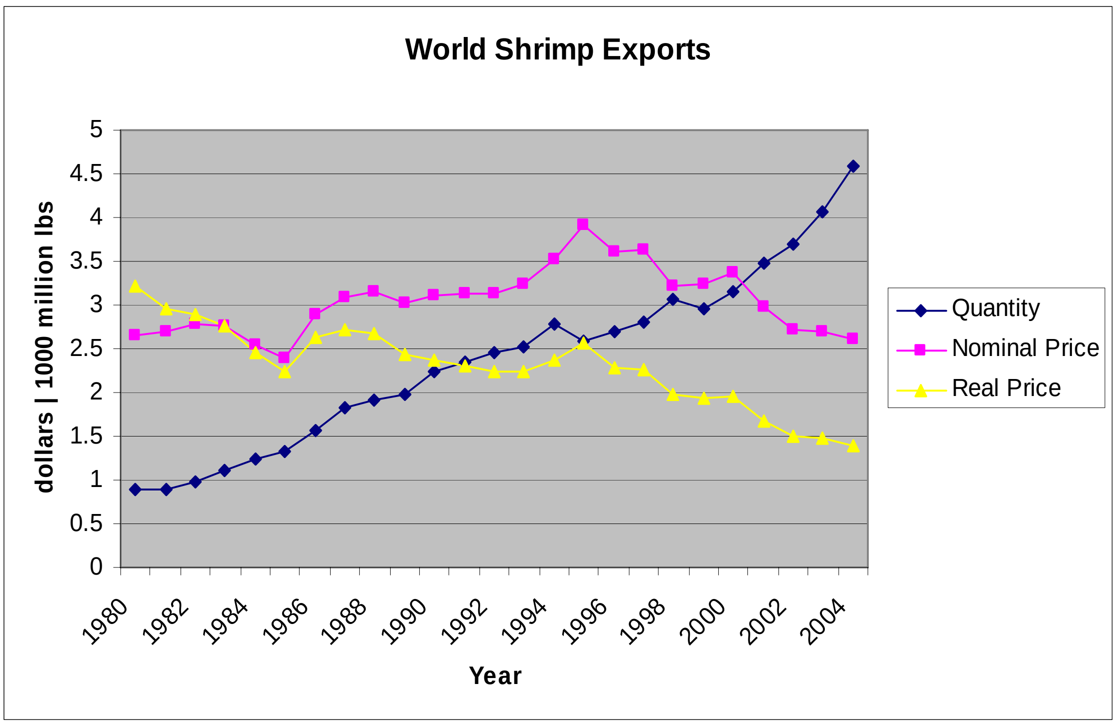

Figure 1.6: Export quantities and prices of Shrimp in International Market

In general, the nominal world shrimp export price trended upwards from 1980 through the mid-1990s and declined thereafter (Figure 1.6). When expressed on a deflated basis (1982-84 U.S. CPI is used as the base), however, a continuous decline in

[3] The imprecision largely reflects the fact that exported product is reported on a product-weight basis. This is compared to world production which is converted to a headless shell-on weight.

price is evident. In 2004, the deflated price of shrimp was $1.38 per pound, which is 57% less than the deflated price in 1980.

1.3.1.1 Major Exporters

Asia is the largest shrimp exporter in the world. Five out of top ten exporting countries, both in terms of quantity and value, are from Asia. According to FAO, Thailand has been the largest exporting country since 1990. Annual Thai exports have consistently been around 500 million pounds since 1994. India and China are generally the next two largest exporting countries. Vietnamese exports have increased from 66.2 million pounds in 1990 to more than 313 million pounds in 2004. Other major warm-water shrimp exporting countries include Indonesia, Brazil and Ecuador.

1.3.1.2 Major Importers

United States and Japan are the two largest shrimp importing nations. Until the mid-1990s, Japan imported larger quantity of shrimp than the United States. Since the mid-1990s, however, America has surpassed Japan as the largest shrimp importer.

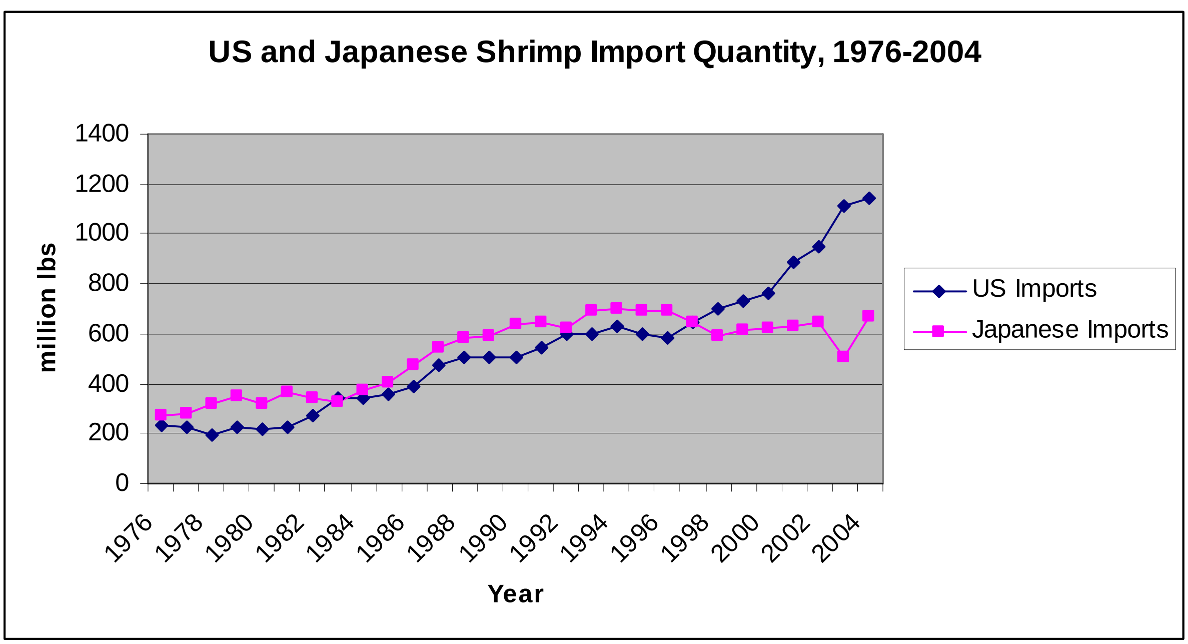

Figure 1.7: US and Japanese Shrimp Import quantity.

In 2004, the United States imported 1.1 billion pounds of shrimp (product weight), valued at $3.68 billion. Japanese imports for the same year totaled 666 million pounds, valued at $1.94 billion. Compared to 1990, US imports have increased by 121%, whereas Japanese imports have remained relatively stable, averaging about 650 million pounds annually (with the exception of 2003 when it decreased to 504 million pounds). A comparison of U.S. and Japanese shrimp imports, both expressed on a product-weight basis, is presented in Figure 1.7. As indicated, U.S. imports have risen sharply since 1997 whereas no growth in Japanese imports is evident.

The Japanese shrimp import market is dominated by shrimp of Asian origin. Primary Asian exporters to Japan include Indonesia, Vietnam, China and Thailand. During the 1990-2004 period, the Asian share of the Japanese imported shrimp market has averaged about 80% (Figure 1.8). Other countries that export shrimp to Japan include Russia, Australia, Greenland and more recently, Canada.

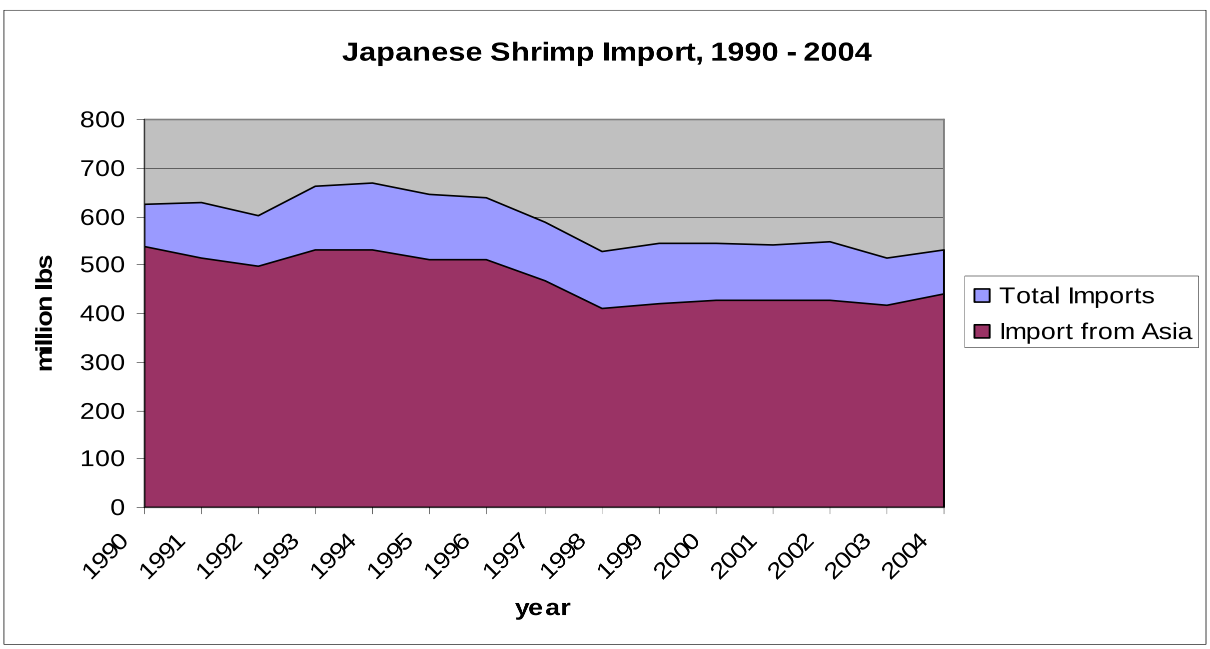

Figure 1.8: Total Japanese shrimp imports and imports from Asia

The European Union also imports a significant quantity of shrimp. Unlike the United States and Japan, a very large proportion of the E.U. imports reflect cold-water shrimp (denoted by Rest of the World in Figure 1.9). However, the European Union also imports a large amount of shrimp from Asia and South America (Figure 1.9).

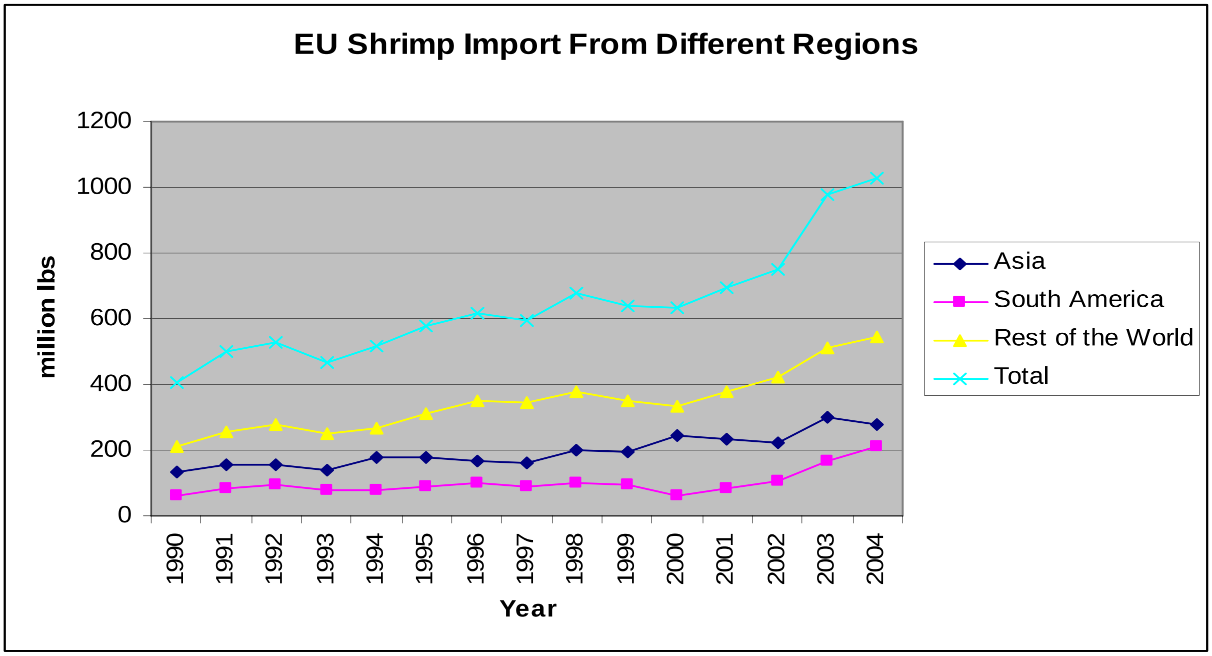

Figure 1.9: European Union Shrimp Imports from Different Regions, 1990 – 2004

1.4 US Shrimp Imports

The majority of US shrimp imports are fresh, frozen or canned[4]. Asia is the largest exporter to the United States and exports from this region to the United States represented 72% of total 2004 U.S. imports. Among the Asian countries, Thailand, China, India and Indonesia are the dominant exporters to the United States. Since the mid 1990s, however, Vietnam's exports to the United States have increased significantly and Vietnam is currently one of the larger suppliers of shrimp to the U.S. market. Since the early 1990s, Thailand has been the largest supplier to the U.S. market. During the 1990-

[4] Discussion in this section pertains only to these products.

2001 period, Thai product represented more than one-half of total U.S. imports. Its share, however, fell to less than 40% by 2004. The declining share reflects increased exports to the U.S. from other countries rather than declining exports to the U.S. from Thailand.

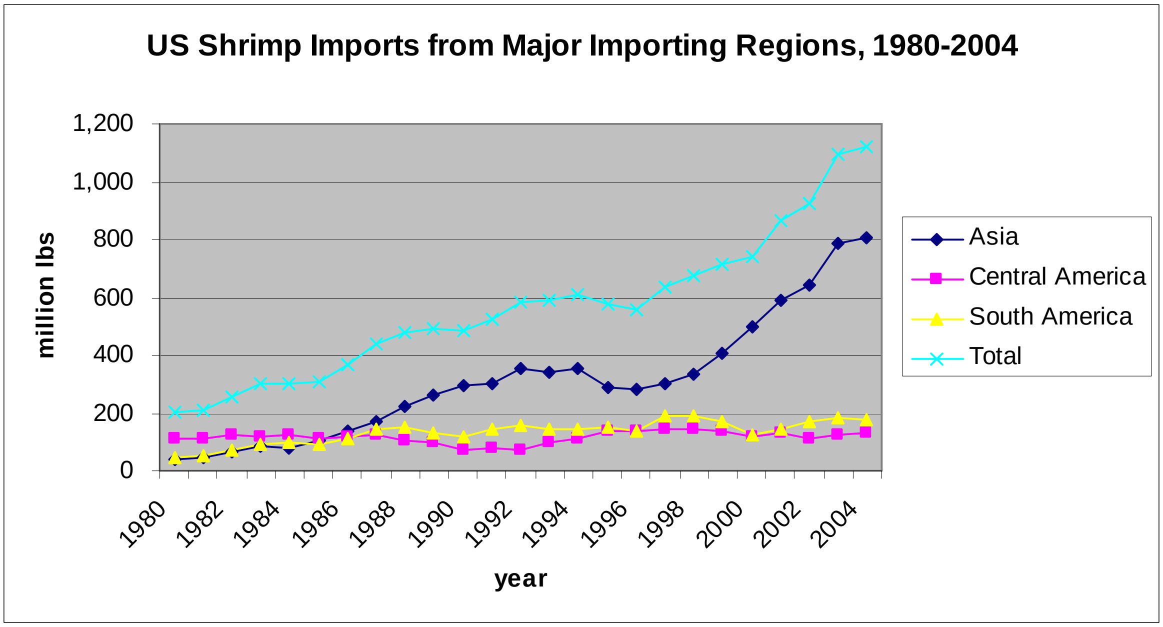

Figure 1.10: US Shrimp Imports from Major Importing Regions, 1980 – 2004

Mexico is the primary supplier of shrimp to the U.S. from the Central American region. During the study period of 1990 to 2004, Mexico's share to the U.S. market from the Central American region has consistently exceeded 45% of the total. Other major countries in this region include Honduras, Panama, El Salvador, Nicaragua, and (more recently) Belize. Overall, a large proportion of Central American production is exported to the United States.

The primary supplier of shrimp to the U.S. from South American region is Ecuador. Throughout the 1990s, almost 70% of shrimp coming into the US from South America was of Ecuadorian origin. Ecuador's share declined sharply in 1999 and 2000 (reaching a low of 35%) due to disease, but has since increased to pre-1999 levels. Other major shrimp exporters from South America include Brazil, Venezuela and Guyana.

1.5 U.S. Domestic Production

The majority of U.S. domestic shrimp production is warm-water shrimp, harvested from the wild and primarily from the Gulf of Mexico. Domestic production in the United States is small compared to imports. In 2004, for example, U.S. imports equaled 1.1 billion pounds (product weight) whereas domestic catch amounted to only 193 million pounds (headless shell-on weight). U.S imports (product weight) and domestic production (headless weight) for the 1990-2004 period are presented in Figure 11.

1.6 Problem Statement

As the previous discussion indicates, world shrimp production has increased rapidly since 1990. As a result, U.S. imports of shrimp have increased, which has culminated in a decline in the deflated harvested price received by U.S. fishermen.

In relation to the size of the world shrimp market, little research has been conducted to assess the impact of increasing shrimp culture on various aspects of shrimp trade. Similarly, only limited research has been conducted to assess the impact of increased world production on the U.S. dockside price. The United States has a large domestic shrimp fishery and changes in the dockside price as a result of increased shrimp production can have major ramifications in the domestic harvesting and processing sectors. . This study attempts to analyze and quantify the impact on Gulf of Mexico dockside price in relation to changes in various world factors, by region (e.g., wild and cultured shrimp production by region).

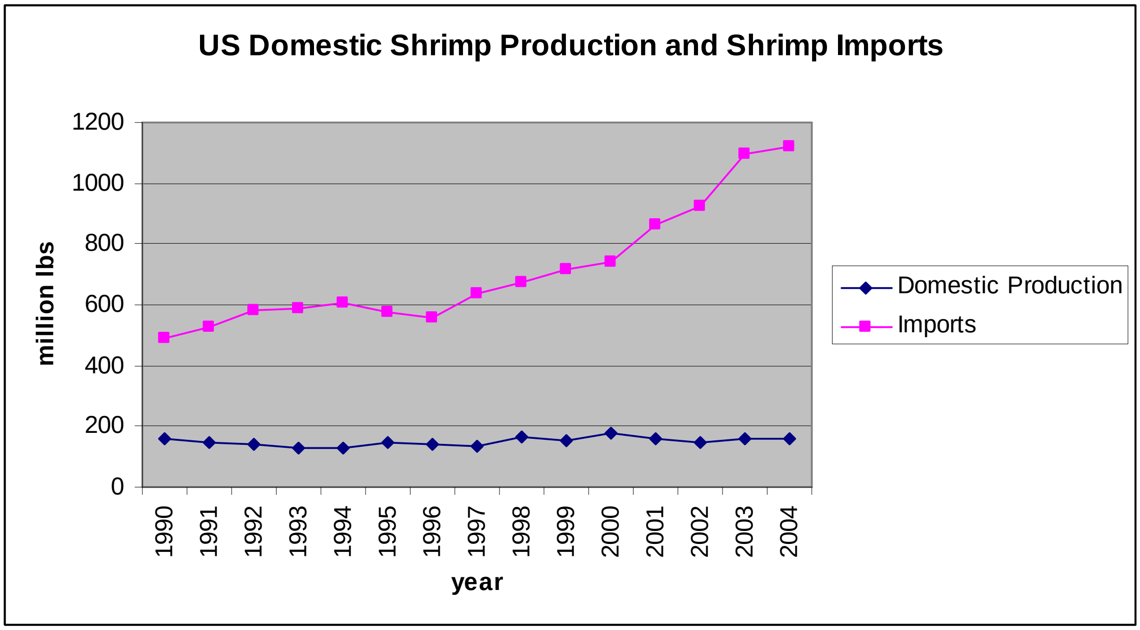

Figure 1.11: Comparison of US domestic shrimp production and US imports, 1990 - 2004

1.7 Objectives

The overall objective of this study is to determine the impact of increasing shrimp production, and hence increasing imports, on the Gulf of Mexico dockside shrimp price. Following specific objectives are proposed to accomplish this goal:

(a) To estimate the import demand for imported shrimp in United States, the European Union, and Japan (i.e., the three major shrimp importers);

(b) To estimate the shrimp import supply equations from the major exporters, Asia, South America and Central America;

(c) To estimate the Gulf of Mexico shrimp inverse demand equation

(d) To solve, in terms of prices, the related export supply/ import demand equations in reduced form;

(e)To substitute the reduced form equations derived from the import demand/export supply equations (expressed in terms of price) into the dockside price equation to predict the effect of increasing import base on the dockside price.

CHAPTER II

LITERATURE REVIEW AND MODEL SPECIFICATIAON

2.1 Trade Models

Two typical classes of trade models have been extensively discussed and empirically tested in the economic literature; the perfect substitute model and the imperfect substitute model. As suggested by its name, the perfect substitute model implies that the domestic and the imported goods are perfect substitutes for one another. Similarly, the imperfect substitute model implies that the domestic and imported products are imperfect substitutes for one another.

The simplest of the imperfect substitute model, as suggested by Magee (1975), assumes that the world can be divided into an importing region and an exporting region. The quantity of imports demanded by the importing region can then be expressed as a function of its own income, the price of imports, and the price of similar domestically-produced goods. The quantity of exports supplied by the exporting region can be expressed as a function of export price received by the producers in the region, and the price of similar goods in the exporting region. The quantity imported by the importing region must equal the quantity exported by the exporting region. The import price can be expressed as a function of the export price, the exchange rate between the two regions and tariff rate for the imported goods, if present. These relationships can be represented by the following four equations:

$$QM_j = f(Y_j, PM_j, P_j)$$
$$QX_i = g(PX_i, P_i)$$
$$QM_j = QX_i$$
$$PM_j = EXR_{ij}(1+T_j)PX_i$$

where the subscripts i and j represent the importing region and exporting region, respectively; QM_j represents the import quantity; Y_j represents the income of the importing region; PM_j represents the import price; P_j represents the price of similar domestically-produced goods; QX_i represents the export quantity; PX_i represents the export price; P_i represents the price of the similar good in the exporting region; EXR_{ij} represents the exchange rate between the importing and the exporting region; and T_j represents the tariff rate (if any) imposed on imports from region i

Goldstein and Khan (1985) suggest that the import demand function, as specified above, can be derived from the conventional demand theory, which implies that the consumers maximize their utility subject to a budget constraint.

The supply side has traditionally been the most "contested and unresolved subject in empirical trade work" (Goldstein and Khan, 1985). Conventional economic theory suggests that the supply of exports will expand as long as there are profits to be generated. Following this, it can be expected that the marginal effect of export price on export quantity will be positive while that of domestic price on export quantity will be negative. It is assumed that these effects will be equivalent in magnitude but in opposite directions; i.e. ${}^{\delta QX_i}\!/_{\delta PX_i} = -{}^{\delta QX_i}\!/_{\delta P_i}$.

As suggested by the trade models presented by Magee (1975) Goldstein and Khan (1985), the researcher must make a number of decisions when empirically modeling international trade in a given commodity or group of commodities. The first question that must be addressed is that of substitutability (i.e., are the commodities perfect or imperfect substitutes). Shrimp produced in the different regions described above, by nature, are not perfect substitutes. They differ in, among other things, size, prices, species, and level of processing involved. Hence, the imperfect substitute model is preferred for the current study.

2.2 Demand Considerations

Two alternative import demand models- the Armington model and the Almost Ideal Demand System- are considered herein. The first model, proposed by Armington (1969), developed a theory to model the international demand for commodities, distinguished by the kind of goods or by the place of origin. This model is popularly known as the Armington model and has been extensively used to study the export or import demand of commodities in a country, or internationally. The second model, referred to as the AIDS model, was proposed in 1980 and differs from the Armington model in terms of the assumptions regarding substitutability among goods.

2.2.1 Armington Model

2.2.1.1 Theoretical Considerations

The Armington model is conceptually based on assumption of two stage budgeting imperfect substitutability between different commodities, or similar commodities with different place of origin. The first stage constitutes determining total demand of the commodity in question and the second stage constitutes determining quantities to be consumed from various sources, which add up to the total quantity demanded (Armington, 1969).

The first step of Armington's approach maximizes an importing country's weakly separable utility function subject to fixed total expenditure, which results in a system of first stage Marshallian demand equations, represented by $Q_i = Q_i(E, P_1,\ldots,P_n),\ i=1,\ldots n.$ The variable E represents total expenditure of the importing country; P_i represents an aggregate price index; and Q_i represents an aggregate quantity index. The number of groups of goods is n. P_i and Q_i must be linearly homogenous to satisfy the consistency requirements of two stage budgeting. The index function must be homothetic for the two stage optimization to be consistent. Furthermore, if the index functions are linearly homogenous, it ensures that group expenditures equal the product of corresponding price and quantity indices (Davis and Kruse, 1993).

David and Kruse further state that the Armington model deviates from convention in its second stage and the dual problem is solved. Expenditures are minimized subject to the utility index. The CES aggregator function is used for Q_i to satisfy the requirement of a linear homogenous utility index. The second stage problem is:

$$\min_{q_0} E_i = \sum_{j=1}^{m} p_{ij} q_{ij} \quad \text{s.t.} \quad Q_i = \left(\sum_{j=1}^{m} b_{ij} q_{ij}^{-\tau_i} \right)^{-1/\tau_i} \quad i = 1,2,.....,n.$$

where p_{ij} and q_{ij} are the price and quantity of good i from source j; E_i is the toral expenditure on group i; and $b_{ij} \in [0,1] \; \forall \; j$, $\sum_j b_{ij} = 1$. The solution to this problem is the conditional Hicksian demand equation:

$$q_{ij} = b_{ij}^{\sigma_i} Q_i \left({p_{ij}}/{P_i} \right)^{-\sigma_i} \quad j = 1,2,...,m.$$

The elasticity of substitution is $\sigma = (1+\tau_i)^{-1}$, and Q_i and P_i are the Constant Elasticity of Substitution (CES) quantity and price respectively. This Hicksian equation is referred to as the Armington equation. This equation can also be written in the form of Market share form, without altering the results, as:

$$q_{ij} / Q_i = b_{ij}^{\sigma} \left(p_{ij} / P_i \right)^{-\sigma} \quad j = 1,2,....,m$$

There are three basic assumptions underlying the Armington framework: (a) the marginal rate of substitution between any two products is independent of the quantity of any other produce; (b) the elasticity of substitution between any two products in one market equals the elasticity of substitution between any two other products in the same market; (c) the elasticity of substitution between any two products in a given market is constant (Duffy *et. al.,* 1990).

2.2.1.2 Extensions to the Original Model

Since its original introduction in 1969, several modifications to the original model have been proposed. Two modifications which are relevant to the current study include the consideration of partial adjustment and inclusion of a trend.

Since actual adjustments are not instantaneous, a partial adjustment framework is often used to estimate import demand. The desired market share, in the Armington formulation, can be represented as follows:

$$\ln(DS_{jt}) = \sigma^* * \ln(b_j) - \sigma^* * \ln(p_{jt} / P_t),\ j = 1,2,.....m$$

where DS_{jt} is the desired level of market share of product j at time t, p_{jt} is the price of good j at time t, P_t is the overall price index for all the m goods in the group, and σ^* is the long run elasticity of substitution.

The partial adjustment model, which expresses the relationship between the actual and the desired market share, can be expressed as:

$$\ln(AS_{jt}) - \ln(AS_{jt-1}) = \gamma\left\lfloor \ln(DS_{jt}) - \ln(AS_{jt-1}) \right\rfloor \qquad 0 < \gamma < 1$$

where AS_{jt} and AS_{jt-1} are the actual market share of the product j in time period t and $t-1$ respectively, and γ is the adjustment factor, which indicates the speed of adjustment. Rearranging the above two equations yields:

$$\ln(AS_{jt}) = \gamma * \sigma^* \ln(b_j) - \gamma * \sigma^* l \ln(p_{jt} / P_t) + (1-\gamma) * \ln(AS_{jt-1})$$

where $\gamma * \sigma^* = \sigma$ is the short run elasticity of substitution.

To account for changes over time that are not related to prices, a trend variable can be included in the model. Following Sarris (1983) and Duffy *et. al.* (1990), the intercept b_j is assumed to be a function of time, so that $b_j = A_j T_j^{\beta}$.

Substituting this value of b_j, yields:

$$\ln(AS_{jt}) = \gamma * \sigma^* \ln(A_j) - \gamma * \sigma^* \ln(p_{jt} / P_t) + (1-\gamma) * \ln(AS_{jt-1}) + \gamma * \sigma^* * \beta_j \ln(T)$$

2.2.1.3 Empirical Analyses Using the Armington Model

Since its introduction, the Armington model has been popularly used in computing demand elasticities of differentiated products in international trade. Johnson *et. al.* (1977) used the model to study the effect of monetary devaluation and foreign trade controls on US wheat imports and US domestic wheat price. Babula (1987) used a multi-regional Armington framework to estimate the demand elasticity of cotton produced in various regions of the United States.

Duffy *et. al.* (1990) used the Armington model to estimate the elasticity of import demand for US cotton. They argue that earlier studies using Armington model are unable to give "total" elasticity, as defined by Buse (1958). They extend the Armington model to include the feedback effects of US cotton prices on cotton prices in other countries. This, they argue, gives rise to a more realistic estimate of elasticity estimates.

Davis and Kruse (1993) pointed out that in traditional Armington models, approximation bias arises due to "misrepresentation" of the quantity index used in the second stage problem. They argue that this bias is self imposed due to minimization in the second stage, which results in a Hicksian demand equation – a function of latent utility and price indices. They show that maximizing, instead of minimizing, in the second stage leads to a Marshallian demand equation which is a function of only observable variables. They argue that this eliminates biases. They used Japanese wheat demand data to compare the traditional Armington model with their "primal" Armington model. The results indicate that the primal model satisfies the sufficient conditions for two-staged budgeting, whereas the traditional model does not satisfy them.

2.2.2 AIDS Model

2.2.2.1 Theoretical Considerations

Since its introduction by Deaton and Muellbauer in 1980, the Almost Ideal Demand System (AIDS) and its variant (the Linear Approximation of AIDS (LA/AIDS)) have been used extensively to model demand systems. Deaton and Muellbauer arrived at the AIDS model by using PIGLOG preferences ordering, which allows perfect aggregation over consumers, via the cost (or expenditure) function. The AIDS demand function put forth by them is in form of the budget share of each of the commodity. Provided the given sets of restrictions hold, the system of equations represents a set of demand functions which add up to total expenditure, are homogenous of degree zero in prices and total expenditure taken together and satisfy Slutsky symmetry.

Deaton and Muellbauer argue that their model is 'almost ideal' because it satisfies the axioms of choice exactly: (a) it aggregates perfectly over consumers without invoking parallel linear Engel curves; (b) it has a functional form which is consistent with known household-budget data; (c) it is simple to estimate, largely avoiding the need of non-linear estimation[5]; and (d) it can be used to test the restriction of homogeneity and symmetry through linear restriction on fixed parameters. The authors argue that though the previously existing Rotterdam or translog models include one or more of these properties, none of the existing models possess all of the properties simultaneously. The flexibility of AIDS cost function, in its functional form, allows the demand function derived from it to be first order approximation of any set of demand functions derived from utility maximizing behavior, making AIDS as general as any other flexible form model (e.g., the Rotterdam or translog systems) (Deaton and Muellbauer, 1980).

In its most general form, each equation in the AIDS framework can be expressed as:

$$W_{it} = \alpha_i + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i (\ln X_t - \ln P_t)$$

where, W_{it} represents the share of the ith good in time period t; p_{jt} represents the price of the jth good in time t ; X_t represents total expenditure on n goods in the system in time period t; $\ln (P_t)$ is a price index; and α_i, β_i, and γ_{ij} are parameters associated with the system.

Deaton and Muellbaur used a translog price index, which makes the demand system non linear. To avoid non linearity, they suggested that the translog price may be approximated by a Stone price index, given by $\ln P_t = \sum_i W_{it} \ln p_{it}$.

[5] The authors provide a way of avoiding non linear estimation by using a linear price index in place of the non linear price index used by them, and they suggest the use of Stone's index proposed by Stone (1953). They emphasize, however, that the use of linear price index leads only to an approximation of the system given by using the non linear index.

The regularity conditions, implied by budget constraints and utility maximization, impose the following restrictions to the system:

Adding up: $\sum_i \alpha_i = 1$, $\sum_i \gamma_{ij} = 0$, $\sum_i \beta_i = 0$

Homogeneity: $\sum_j \gamma_{ij} = 0$

Symmetry: $\gamma_{ij} = \gamma_{ji}$; $i \neq j$

The adding up condition may lead to a singular covariance matrix. In that case, the system can be estimated by removing one equation from the system. The system is invariant to which equation is dropped, and the parameters of the dropped equation may be retrieved by using the adding up conditions (Asche *et. al.,* 1997).

2.2.2.2 Extensions to the Original Model

A number of modifications have been made to the AIDS/LAIDS model initially proposed by Deaton and Muellbauer (1980). Modifications relevant to the current study are examined below.

While the Stone's price index has been used extensively in conjunction with estimation of the AIDS model, recent evidence has shown that the use of this index can yield inconsistent parameter estimates (Asche and Wessells,1997).. Following suggestions by Moschini (1995), Asche and Wessels recommend the use of various other indices (e.g., the Tornqvist index, corrected Stone price index) in lieu of the traditional Stone's price index. Furthermore, they show that when the prices are normalized to unity, AIDS and LA/AIDS are equivalent when evaluated at the point of normalization, which will stand true if any of the above mentioned price indices are used to estimate the LA/AIDS. Finally, they show that both compensated and uncompensated own price, cross price, and expenditure elasticities are same for AIDS and LA/AIDS when calculated at the point of normalization.

Wahl and Hayes (1990) provide the basis for using LA/AIDS with an upward sloping supply curve. Previous work involving demand systems, including that of Deaton and Muellbauer, had maintained the assumption of perfectly elastic supply. Wahl and Hayes demonstrated that imposing this assumption can lead to simultaneous equation bias, (causing underestimation of price responsiveness), when, in fact, the quantity supplied is responsive to the output price. They compare the results of demand system estimation using Iterative Seemingly Unrelated Regression (i.e., meat supply equations are perfectly elastic) and Iterative Three Stage Least Square regression (i.e., meat supply equations are assumed to be upward sloping) for Japanese meat demand. Empirical results indicated that using Iterative Seemingly Unrelated Regression results underestimate the elasticities and the estimated elasticities under the Iterative Three Stage Least Square regression framework were more price responsive.

Finally, Thompson (2004) raises the issue of effect of group expenditure in elasticities estimated by using Almost Ideal systems. Most of the literature in AIDS maintains group expenditures to be exogenous. Thompson argues that even though the prices of the goods may be exogenous, a change in any of the prices might influence the consumers' decisions about the group expenditures. This would represent an additional effect which is not captured by the AIDS framework. Similarly, the effect of change in price of goods outside the group may only be captured through a group expenditure term. He suggests adding a simple group expenditure equation in the system and estimating it simultaneously with the model. However, he states that estimation of LA/AIDS will lead to further complexities while computing the elasticities, and hence should be avoided. He concludes that adding the group expenditure term may not be panacea because it may lead to violation of theoretical restrictions, like symmetry.

2.2.2.3 Elasticity Estimates and Marginal Effects for LA/AIDS Model

Many approaches are found in the literature for calculating the elasticities for LA/AIDS models. The most commonly used approach is to use formulae suggested by Chalfant (1987). Alston *et. al.* (1994) discuss the problems associated with the elasticities of both the full AIDS model and its linear approximation and suggest the use of Chalfant's formulae for linear approximation of AIDS. Edgerton *et. al.* (1996) also suggest that Chalfant's formulae are 'quite reliable'. These are given by Seale and Merchant (2002) as follows:

(a) *Conditional Expenditure Elasticity:*

Conditional Expenditure Elasticity, $\eta = 1 + \beta / W$,

(b) *Marginal Shares*:

Marginal Share, M = $\beta_i + W_i$

(c) *Conditional Own Price Elasticity*:

(c.1) *Slutsky (Compensated) Own Price Elasticity*,

$$S_{ii} = -1 + \left(\gamma_{ii} / W_i\right) + W_i$$

.(c.2) *Cournot (Uncompensated) Own Price Elasticity,*

$$C_{ii} = -1 + \left(\gamma_{ii} / W_i\right) + \beta_i$$

(d) *Conditional Cross Price Elasticity:*

(d.1) *Slutsky (Compensated) Cross Price Elasticity*,

$$S_{ij} = -1 + \left(\gamma_{ij} / W_i\right) + W_j , i \neq j$$

(d.2) *Cournot (Uncompensated) Cross Price Elasticity*,

$$C_{ij} = -1 + \left(\gamma_{ij} / W_i\right) - \beta_i * W_j / W_i, i \neq j$$

2.2.2.4 Empirical Analyses Using AIDS/LAIDS Model

As indicated, an increasing number of import demand studies have utilized the AIDS/LAIDS model for estimation purposes. Two studies which are relevant to the current analysis include Asche, Bjorndal and Salvanes (1998) and Seale and Merchant (2002).

Asche, Bjorndal and Salvanes (1998) used the LA/AIDS system to evaluate the demand of salmon from different origins and of different product types in the European market. They consider fresh Atlantic salmon, frozen Atlantic salmon and frozen Pacific salmon as the three main products (i.e., the most important product forms imported to the European Union). By choosing only the three product forms, they implicitly assumed weak separability among the three as well as with other goods in the consumer's bundle. They employed the corrected Stone price index, which they argued, satisfies the commensurability property[6]. Finally, they calculated the compensated and uncompensated elasticities for the different product forms using the formulae suggested by Chalfant (1987).

Seale and Merchant (2002) used the AIDS system to analyze the US red wine market. For purposes of analysis, they considered US wine imports from seven regions - Italy, France, Spain, Australia, Chile, the rest of the world, and domestic (i.e., the United States) production – as potential substitutues/complements. They use the conditional

[6] The corrected Stone Price index maintains invariance with respect to units used in the analysis.

own-price and cross-price elasticity formulae suggested by Chalfant to arrive at the compensated and uncompensated elasticities.

2.3 Supply Considerations

The theory of export supply in the trade literature tends is somewhat less developed then import demand. In general, the focus of much of the new trade theory (see Carter and MacLaren) revolves around the issue of imperfect competition (and or non-homogenous goods) among exporting countries. For purposes of the current study, however, the assumption of perfect competition is employed. As such, conventional economic theory suggests that the supply of exports will expand as long as there are profits to be generated. Following this, it can be expected that the marginal effect of export price on export quantity will be positive while that of domestic price on export quantity will be negative and that these effects will be equivalent in magnitude but in opposite directions. Similarly, if an exporting country *(denoted i)* has two possible destination markets (say, *j* and *k*), the marginal effect an increase in export price to country *j* relative to country *k* should, in theory, result in an increase in exports from country *i to country j* and an equal decrease in exports from country *i* to country *k*.

2. 4 Shrimp Trade Model

2.4.1 Shrimp Import Demand and Export Supply Considerations

To examine the world shrimp market, data spanning the period 1990-2004 was utilized in the analysis. The shrimp model developed for the current study consists of a number of demand and supply equations that, together, determine the allocation of shrimp between the three primary importing regions – the United States, the European Union, and Japan. As discussed in Chapter 1, the United States imports warm-water shrimp from three principal regions – Central America, South America, and Asia. The European Union, by comparison, imports warm-water shrimp from two principal regions- Asia and South America. The European Union, however, also imports a large amount of cold-water shrimp which may compete directly with the warm-water product in the market. Finally, almost all of the imports to Japan originate from other Asian countries. Hence, import demand for the United States and the European Union are initially estimated via a systems approach (based on the AIDS/LAIDS specification) while Japanese import demand is specified as a single equation. These models are considered in more detail below. Given differences in theoretical considerations, an Armington model for the U.S. import market is also presented.

To model the supply, a set of primary supply equations are built for Asia and South America, and another set of allocation equations are built to determine the supply of each region to the major consumers. For Central America, however, a single supply is estimated, since the United States is the most important and the biggest importer from the region.

The United States, while a large shrimp importer, also produces large annual harvests of warm-water shrimp; primarily from the Gulf of Mexico. Since the 1990's, domestic production as a percent of total shrimp supply (i.e., domestic production and imports) has fallen sharply, averaging about 15% in recent years. While including domestic production in the AIDS/LAIDS model of import demand is consistent with theory, inclusion is problematic because the size of the harvested product changes significantly during the course of a year. The change in price during the course of the year is likely not as related to underlying changes in demand and supply but rather changes in the average size of shrimp at harvest. Specifically, there is a strong inverse relationship between the number of shrimp per pound and the per pound price. Harvests of small shrimp in the Gulf occur primarily in the spring and early summer (associated with the life-cycle of the shrimp and the opening of inshore waters in the respective Gulf States) and the average dockside prices tend to be relatively low during this period. Given that the domestic product is not homogeneous throughout the course of the year, this product was not included in the import demand system. Rather, as discussed below, it was estimated as a separate equation.

2.4.1.1 Import Demand Equations

2.4.1.1.1 U.S. and E.U Import Demand Equations

2.4.1.1.1.1. The Armington Model

The Armington model, as previously discussed (with the relevant extensions), provides the basis for the U.S. import demand model. Letting the Greek symbols represent the parameters, the functional form of the Armington model to be estimated for this study is given by:

$$\ln(AS_{jt}) = b_{j0} - b_{j1} * \ln(p_{jt} / P_t) + b_2 * \ln(AS_{jt-1}) + b_{j3} \ln(T).$$

For any specific region (i.e., Asia, Central America, and South America) the specific equation to be estimated can be represented as:

$$\ln(AS_{jt}) = b_{j0} - b_{j1} * \ln(p_{jt} / P_t) + b_2 * \ln(AS_{jt-1}) + b_{j3} \ln(T) + b_{j4} * ydum + b_{j5} * D_1 + b_{j5} * D_1 + b_{j5} * D_1$$

where the subscripts j = 1,2 and 3 represents Asia, South America and Central America respectively. As with the AIDS/LAIDS model, quarterly dummy variables are included in the analysis. Additionally, a dummy variable representing pre-and-post 2001 is introduced into the model.[7] The price index used in this study is the weighted price of the total imports into the US, calculated as the ratio of total value of US shrimp imports to the total quantity of US shrimp imports.

2.4.1.1.1.2 AIDS/LAIDS Shrimp Import Demand Equations

Based on the theoretical discussion, each equation in the LA/AIDS system representing US and EU shrimp import demand can be written as[8]:

$$W_{it} = \alpha_i + \sum_j \gamma_{ij} \ln p_{jt} + \beta_i (\ln X_t - \ln P_t) + \sum_{i=1}^{3} \delta_i D_i$$

where D_i = quarterly dummy variable

$\forall$ D_1 = 1 for first quarter and 0 otherwise

D_2 = 1 for second quarter and 0 otherwise

D_3 = 1 for third quarter and 0 otherwise

Since this study uses quarterly data, dummy variables are added to the model to capture quarterly variation in the demand (the fourth quarter is deleted).

In accordance with the above model, the LA/AIDS equations for the demand of shrimp in the US can be written as

$$W_{asia} = \alpha_a + \gamma_{aa} * \ln(cpia) + \gamma_{ac} * \ln(cpic) + \gamma_{as} * \ln(cpis) + \beta_a * \left[\ln(tval) - \ln(P)\right] + \delta_{a1} * D_1 \\ + \delta_{a2} * D_2 + \delta_{a3} * D_3$$

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[7] The price of domestic production fell sharply beginning in late 2001 (primarily after the September 11 event) and is thought to be related, at least in part, to a decline in away-from-home consumption (shrimp is primarily consumed in the away-from-home market). The introduction of this dummy variable was used to "capture" any changes that might have occurred.

[8] As indicated, the AIDS model rather than an inverse AIDS model is used to estimate U.S. and E.U. import demand. There is little question that such a specification is appropriate for the Asian and South American product since alternative markets exist for these products. With respect to Central American, produced product can either be exported (almost entirely to the United States) or consumed in the home market which provides at least some justification for AIDS specification. However, additional research may consider a mixed model where the quantity of the Central American product is considered fixed (little is known with respect to the cold-water shrimp in the European market).

$$W_{cam} = \alpha_c + \gamma_{ac} * \ln(cpia) + \gamma_{cc} * \ln(cpic) + \gamma_{cs} * \ln(cpis) + \beta_c * \left[\ln(tval) - \ln(P)\right] + \delta_{c1} * D_1$$
$$+\delta_{c2} * D_2 + \delta_{c3} * D_3$$

$$W_{sam} = \alpha_s + \gamma_{as} * \ln(cpia) + \gamma_{cs} * \ln(cpic) + \gamma_{ss} * \ln(cpis) + \beta_s * \left[\ln(tval) - \ln(P)\right] + \delta_{a1} * D_1$$
$$+\delta_{a2} * D_2 + \delta_{a3} * D_3$$

while the linear price index (corrected Stone Index) for the US shrimp demand is represented by

$$\ln(P) = W_{asia} * \ln\left[cpia_t - cpia_0\right] + W_{cam} * \ln\left[cpic_t - cpic_0\right] + W_{cam} * \ln\left[cpis_t - cpis_0\right]$$

The variables W_{asia}, W_{cam} and W_{sam} represent the share of U.S imports originating from Asia, Central America, and South America, respectively. Similarly, cpia, cpic, and cpis refer to the corresponding nominal U.S import prices (normalized at their respective mean values) from the respective regions. The variable tval represents the total value of U.S. shrimp imports from the relevant regions (i.e., Asia, Central America, and South America) while ln(P) represents a linear price index. Finally, $cpia_0$, $cpic_0$, and $cpis_0$ represent the 1990 nominal U.S, import prices from each of the three respective regions (i.e., Asia, Central America, and South America).

Similarly, the AIDS equations for the demand for shrimp in the EU can be written as

$$W^e_{asia} = \alpha^e_a + \gamma^e_{aa} * \ln(cpia) + \gamma^e_{as} * \ln(cpis) + \gamma^e_{ar} * \ln(cpir) + \beta^e_a * \left[\ln(tval^e) - \ln(P^e)\right] + \delta^e_{a1} * D_1$$
$$+\delta^e_{a2} * D_2 + \delta^e_{a3} * D_3$$

$$W^e_{sam} = \alpha^e_s + \gamma^e_{as} * \ln(cpia) + \gamma^e_{ss} * \ln(cpis) + \gamma^e_{sr} * \ln(cpir) + \beta^e_s * \left[\ln(tval^e) - \ln(P^e)\right] + \delta^e_{s1} * D_1$$
$$+\delta^e_{s2} * D_2 + \delta^e_{s3} * D_3$$

$$W^e_{row} = \alpha^e_r + \gamma^e_{ar} * \ln(cpia) + \gamma^e_{sr} * \ln(cpis) + \gamma^e_{rr} * \ln(cpir) + \beta^e_r * \left[\ln(tval^e) - \ln(P^e)\right] + \delta^e_{r1} * D_1$$
$$+\delta^e_{r2} * D_2 + \delta^e_{r3} * D_3$$

The linear price index (corrected Stone Index) for the US shrimp demand is represented by

$$\ln(Pe) = W^{e}_{asia} * \ln\left[cpia^{e}_{t} - cpia^{e}_{0}\right] + W^{e}_{sam} * \ln\left[cpis^{e}_{t} - cpis^{e}_{0}\right] + W^{e}_{row} * \ln\left[cpirow^{e}_{t} - cpirow^{e}_{0}\right]$$

The variables W^{e}_{asia}, $W^{e}_{sam,}$ and W^{e}_{row} represent the share of E.U. imports originating from Asia, Central America, and the "rest of the world," (i.e., cold-water shrimp), respectively. Similarly, $cpia^{e}$, $cpis^{e}$, and $cpirow^{e}$ refer to the corresponding nominal E.U shrimp import prices from the respective regions (normalized at their respective mean values). The variable $tval^{e}$ represents the total value of E...shrimp imports from the designated regions (i.e., Asia, South America, and "the rest of the world'") while $\ln(P^{e})$ is equal to a linear price index for EU. Finally, $cpia^{e}_{0}$, $cpis^{e}_{0}$, and $cpis^{e}_{0}$ represent the 1990 nominal E.U. import prices from each of the three respective regions (i.e., Asia, South America, and the "rest of the world").

Deaton and Muellbauer (1980), as noted, proposed using the Stone Index as a proxy for the linear price index. Because of the known deficiencies associated with this index, this study uses the Corrected Stone Index, used by Asche *et. al.* (1997), which can be written as $\ln P_t = \sum_i W_{it} \ln\left(p_{it} / p_i^0\right)$. The corrected Stone Index modifies the model to the Linear Approximation of AIDS (LA/AIDS).

Prices are normalized at the mean because with normalized prices, the linear and nonlinear AIDS representations are equal at the point of normalization. This allows the use of Chalfant's formulae for uncompensated expenditure, own price and cross price elasticites at the point of normalization, i.e. the mean. Moreover, as the uncompensated elasticites are equal at the mean, the same will be true for the compensated elasticities as computed by using Slutsky equation. Hence, normalization of prices at their means allows for easy calculation of elacticities (Asche and Wessels, 1997).

2.4.1.1.2 Japanese Shrimp Import Demand

Japanese demand for imported shrimp is represented by the following relationship[9]:

$Q_t^J = f\,(P_t^J, INV_t^J, INC_t^J, D)$

where Q^J_t represents the quantity of shrimp exported from Asia to Japan in time period *t;* $P^J{}_t$ is equal to the Asian export price of shrimp to Japan in time period *t*; INV^J_t, is equal to beginning-of-the quarter Japanese shrimp inventories in time period *t*; INC^J_t represents Japanese income(specified in terms of GDP) in time period *t*; and D represents a vector of quarterly dummy variables.

A linear specification for the Japanese import demand equation was used for estimation purposes. It is given as follows:

$$Q_t^J = \alpha_1^J + \alpha_2^J * P_t^J + \alpha_3^J * INV_t^J + \alpha_4^J * INC_t^J + \delta_1^J * D_1 + \delta_2^J * D_2 + \delta_3^J * D_3$$

Japanese import demand is expected to be negatively related to price and inventories and positively related to income. Dummy variables are included to capture the quarterly fluctuation in Japanese shrimp import demand (fourth quarter deleted).

2.4.1.2 Export Supply Equations

Supply equations were identified for the three primary producing regions. These are discussed below.

[9] Theoretically, Japan's domestic production is also likely to influence import demand. However, Japanese shrimp landings are relatively minor in relation to imports. For this reason, and because quarterly harvest data are not available, domestic production is not included as an argument in the equation. Using annual data, Keithly et al. (1993) found that Japanese domestic production did not statistically significantly influence Japanese import demand.

2.4.1.2.1 Asian Supply Equations

Asian supply is allocated between two major markets, the United States and Japan. The European Union is considered to be a residual market. Two equations are specified to allocate the total Asian supply between the two major markets, and one overall Asian supply equation models the overall supply of Asia.

2.4.1.2.1.1 Asian Export Supply to the United States

Asian export supply to United States is expressed as a function of the export prices of shrimp in the US and Japan and total Asian shrimp exports (i.e., exports to the United States, Japan, and the European Union). The Asian export price to the European Union is not included in the analysis because this market is considered a residual export market for the Asian product. Dummy variables are introduced to capture the quarterly variations in export supply. The supply equation for Asian exports to the United States is expressed as:

$$qia_t = \theta_1^A + \theta_2^A * cpia_t + \theta_3^A * cpj\_as_t + \theta_4^A * t\exp_t^A + \delta_1^{AU} * D_1 + \delta_2^{AU} * D_2 + \delta_3^{AU} * D_3$$

where qia_t represents the quantity of shrimp exported to the U.S. from Asia in time period *t;* $cpia_t$ and cpj_as_t represent the Asian export price to the US and Japan, respectively, in time period *t;* $texp_t$ represents total Asian exports (i.e., to the U..S., EU, and Japan) in time period *t;* and $D_{1,2,3}$ represent dummy variables for the first three quarters of each year.

As the export price of shrimp from Asia to the United States increases, *ceteris paribus*, the quantity exported to this market is expected to increase. Hence, the expected sign associated with the parameter θ_2^A is positive. Conversely, however, as the Asian export price to Japan increases, *ceteris paribus,* Asian product is expected to be diverted from the US market to the Japanese market. This would imply an expected negative sign associated with the parameter θ_3^A. Furthermore, an increased in total Asian exports primarily represents increased production in the region (either cultured or wild). As such, the quantity exported to the United States is expected to increase (decrease) with an increase (decrease) in the total Asian exports; implying an anticipated positive sign associated with θ_4^A.

2.4.1.2.1.2 Asian Export Supply to Japan

Asian supply to Japan is analogous to Asian supply to the US. It is expressed as a function of the import prices in Japan and the US, and the total Asian exports.

$$qij_t = \chi_1^A + \chi_2^A * cpia_t + \chi_3^A * cpj\_as_t + \chi_4^A * t\exp_t^A + \delta_1^{AJ} * D_1 + \delta_2^{AJ} * D_2 + \delta_3^{AJ} * D_3$$

Where qij_t represents the quantity of shrimp exported to Japan from Asia in time period t and all other variables are as previously defined.

2.4.1.2.1.3 Total Asian Export Supply

The total Asian export supply is specified as a function of cultured shrimp and captured shrimp produced, and the aggregated Asian income, and quarterly supply shifters.

$$t\exp_t = \lambda_1 + \lambda_2 * acult_t + \lambda_3 * awild_t + \lambda_4 * inc\_a_t + \delta_1^{AT} * D_1 + \delta_2^{AT} * D_2 + \delta_3^{AT} * D_3$$

Where $texp_t$ represents the total exports from Asia (to the U.S., Japan, and the EU) in time period t; $acult_t$ is the reported quantity of Asian cultured shrimp produced in time period t; $awild_t$ is the reported quantity of Asian wild shrimp in time period t; inc_a represents aggregate income for the larger Asian shrimp- exporting countries; and $D_{1,2,3}$ represent dummy variables for the first three quarters of each year.

Increases in either cultured or wild Asian production is anticipated to result in increased exports, *ceteris paribus*. With increases in Asian income, demand for shrimp in the home market can be expected to increase. Hence, one would anticipate a negative relationship between *inc_a* and $texp_t$.

2.4.1.2.2 South American Export Supply Equations

The South American supply equations consist of an equation representing the supply to the United States and an overall South American supply equation.

2.4.1.2.2.1 South American Export Supply to the United States

South American export supply to the United States is expressed as a function of the South American export price to the United States, the export price to the European Union, total South American production and quarterly supply shifters.

$$qis_t = \pi_1 + \pi_2 * cpis_t + \pi_3 * cpeu\_sa_t + \pi_4 * qsam + \delta_1^S * D_1 + \delta_2^S * D_2 + \delta_3^S * D_3$$

Where qis_t represents the quantity of shrimp exported from South America to the United States in time period *t;* $cpis_t$ and $cpeu\_sa_t$ represent the export price of South American shrimp to the U.S. and the E.U, respectively, in time period *t;* and $qsam_t$ represents the total quantity of shrimp exported from South America (to the U.S. and E.U.) in time period *t.* Analogous to the Asian equations, π_2 and π_4 are expected to be positive whereas π_3 is expected to be negative.

2.4.1.2.2.2 Total South American Export Supply

The total South American export supply equation is specified as a function of South American cultured production and the quarterly supply shifters. Since the majority of South American export product originates from Ecuador whose exports primarily reflect cultured product, wild harvest is not included in the South American export supply equation.

$$qsam_t = \rho_1 + \rho_2 * scultq + \delta_1^{ST} * D_1 + \delta_2^{ST} * D_2 + \delta_3^{ST} * D_3$$

Where *scultq* represents the reported South American cultured shrimp production in time period t.

2.4.1.2.3 Central American Export Supply Equation

The United States accounts for well over 90% of Central American shrimp exports with Mexico, the largest shrimp producer in Central America, exporting almost all of its wild production to the U.S. market. For this reason, Central American export supply is modeled by a single equation, specified as the function of export price, (expressed in terms of local currency), quantity of cultured shrimp, quantity of wild shrimp and quarterly supply shifters.

$$qic_t = \phi_1 + \phi_2 * (cpic_t * excame_t) + \phi_3 * ccult_t + \phi_3 * cwild_t + \delta_1^C * D_1 + \delta_2^C * D_2 + \delta_3^C * D_3$$

where qic_t represents the quantity of shrimp exported from Central America to the United States in time period *t;* $cpic_t$ represents the export price of Central American shrimp to the US (expressed in US dollars), in time period *t;* $excame_t$ represents a composite exchange rate among Central American countries for corresponding exporters; $ccult_t$ represents the reported production of cultured shrimp in Central America in time period *t;* and $cwild_t$ represents the Central American production of wild shrimp in time period *t.*

2.4.1.3 U.S. Demand for Domestic Shrimp from Gulf of Mexico

Domestic production of shrimp is relatively fixed in the short-run and is dependent primarily on prevailing environmental conditions. As such, quantity is relatively unresponsive to changes in price. Hence, US demand for domestic shrimp is represented by the following inverse demand relationship:

P_t^d = f (dpia$_t$, dpic$_t$,dpis$_t$, lbs$_t$, avgsize$_t$, pct_hdon$_t$, pct_wht$_t$, inus$_t$)

Where P_t^d represents the deflated price of Gulf of Mexico shrimp landings in time period t; dpia$_t$, dpic$_t$, and dpis$_t$ represent the deflated U.S. import prices from the three principal exporting regions (i.e., Asia, Central America, and South America) in time period t; lbs$_t$ represents Gulf of Mexico landings (expressed on a headless basis), in time period t; avgsize$_t$ represents the average number of shrimp per pound harvested from the Gulf of Mexico in time period t; pct_hdon$_t$ percent of Gulf of Mexico production that is landed on a heads-on basis, in time period t; pct_wht$_t$ represents the percent of white shrimp in the Gulf of Mexico harvest, in time period t; and inus$_t$ represents U.S beginning shrimp inventories in time period t

For estimation purposes, a double log model is used and is expressed as follows:

$$Log(P_t^d) = \alpha_1^d + \alpha_2^d * Log(dpia_t) + \alpha_3^d * Log(dpic_t) + \alpha_4^d * Log(dpis_t) + \alpha_5^d * Log(lbs_t) +$$
$$\alpha_6^d * Log(avgsize_t) + \alpha_7^d * Log(pct\_hdon_t) + \alpha_8^d * Log(pct\_wht_t) + \alpha_9^d * Log(inus_t) +$$
$$\delta_1^d * D_1 + \delta_2^d * D_2 + \delta_3^d * D_3$$

Import prices, rather than import quantities, were used as arguments in the dockside price equation on the premise that imported product is an imperfect substitute for the domestic harvest. Increases (decreases) in any of the import prices (i.e., dpia$_t$, dpic$_t$, and dpis$_t$) are expected to result in an increase (decrease) in the domestic dockside price.. Similarly, an increase (decrease) in domestic production is anticipated to result in a decrease (increase) in the dockside price, *ceteris paribus*. An increases in the average number of shrimp to the pound, as previously discussed, is hypothesized to result in a lower per pound price, *ceteris paribus*.. Higher beginning inventories represent higher initial supplies which, in theory, would reduce import demand. Hence, dockside price is expected to be negatively related to inventories.

2.4.2 Data Sources and Considerations

A brief discussion of the primary data sources used in this study, along with relevant data modifications, is given in this section. Table 1.1 presents the sources of various datasets used for the study.

FAO Fishstat provides annual production of shrimp, by country, in terms of quantity. It also differentiates production by cultured and wild. The data were categorized according to the three primary warm-water producing regions; namely Asia, South America and Central America. The production from the rest of the world was not used in the analysis because it comprises a small percentage of the total and includes virtually none of the warm-water product. The quantity data was converted from metric tons to pounds using the conversion factor of 2204.622 pounds per metric ton.

Table 2.1: Sources of various datasets used in the study

SN	Data	Source	URL
1	Shrimp Production, Wild and Cultured	FAO Fishstat	http://www.fao.org/
2	US Shrimp Imports	National Marine Fisheries Service	http://www.st.nmfs.gov/st1/
3	Japanese Shrimp Imports	National Marine Fisheries Service	http://www.st.nmfs.gov/st1/
4	EU Shrimp Imports	EUROSTAT	http://epp.eurostat.ec.europa.eu/
5	Ag. Exchange Rates	USDA, ERS	http://www.ers.usda.gov/Data/exchangerates/

Production data, however, is provided only on an annual basis while quarterly data are required for analysis. Assuming only limited storage capacity in producing regions, annual production for Asia and South America (both cultured and wild) were converted to a quarterly basis based on quarterly import shares by the primary importing regions (i.e., Japan, the United States, and the European Union). Central American production was converted to a quarterly estimates based on numbers that can be found in Keithly and Diagne (1998)[10].

The National Marine Fisheries Service website provides monthly data on US shrimp imports from various countries in terms of quantities in kilograms and values in US dollars. The monthly data were aggregated on quarterly basis (January-March, April-June, July-September, October-December) from countries in Asia, Central America and South America. The import quantities were converted from kilograms to pounds using the conversion factor of 2.20462 pounds per kilogram. Import values, given in terms of nominal US dollars, were divided by the corresponding quantities yielding nominal prices, in terms of dollars per pound.

Japanese shrimp imports and cold storage holdings data were also available from the National Marine Fisheries Service website. The monthly data were converted to quarterly data and quantities were converted from metric tons to pounds. Import values, given in terms of million yen, were converted to U.S. dollars by using the appropriate exchange rates and then dividing by the corresponding quantities to obtain the nominal import prices in terms of dollars per pound.

Monthly European shrimp import data are available from the Eurostat website. The monthly data were converted to quarterly imports by region (Asia, South America and the rest of the world). Quantities, reported in terms of 100 kilograms, were converted

[10] To determine whether quarterly estimates of production significantly influenced results, production in each year was also assumed to be constant for each quarter (i.e., estimated quarterly production equaled annual production divided by four). Regression results associated with this assumption are presented in Appendix A. In general, results were relatively invariant to method used for allocating annual production to quarterly estimates.

into pounds using the conversion factor of 220.46 pounds per 100 kilo. Values, in terms of nominal Euros, were converted to US dollars by using the appropriate exchange rates.[11].

Aggregated exchange rates, and aggregate income for relevant regions (Asia and Central America), were calculated using the method proposed by Dutton and Grennes (1987). For South America, the GDP and exchange rate for Ecuador were used as representative for the region because majority of South American export in the markets being studied are from Ecuador.

The National Marine Fisheries Service provided monthly data on Gulf of Mexico shrimp harvest (pounds and value) and associated attributes. Attributes included species, catch by size, and pounds landed on a heads-on basis versus headless basis. Finally, the National Marine Fisheries Service was also the source of data for beginning inventories used in the U.S. demand for domestic shrimp equation.[12]

2.4.3 Statistical Considerations

Since the three importing regions considered in this analysis are all major purchasers on the world shrimp market, they can influence export price. Given this fact, each of the export supply and import demand equation will be estimated using iterative three-stage least squares (3SLS) method which will mitigate simultaneity bias that would be associated with estimating each equation separately or in a seemingly-unrelated regression framework. Cultured and wild production from the various exporting regions,

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[11] Monthly data for the years 1990 to 1993 were not available.. Annual data for that period is available from the EU Internal and External Trade Data CD. The annual data were converted to quarterly data based on average quarterly percentages for 1994 to 2004.

[12] The National Marine Fisheries Service ceased collection of inventory data at the end of 2002. As such, quarterly values for 2002 were used as estimates of beginning inventories by quarter in 2003 and 2004.

incomes, and exchange rates are defined as exogenous to the model as well as the dummy variables for the first three quarters of each year and the trend variable are included as exogenous variables.

2.4.4 Reduced Form Considerations

As specified, the import demand and export supply equations outlined in this chapter are structural in nature. Furthermore, the Gulf of Mexico dockside price equation is expressed as a function of import prices rather than import quantities. To examine the impact on dockside price associated with a change in any exogenous variable (included in the import demand/export supply equations) we estimated reduced form equations for the import demand/export supply system. These reduced form equations, expressed on the basis of import price by region, were then substituted into the dockside price equation. This then permitted an examination of the expected change in dockside price associated with a change in any exogenous factor included in the import demand/export supply system.

The software package Mathematica was used to derive the reduced form equations. Attempts to solve reduced form equations using the AIDS model were unsuccessful. Hence, all reduced form equations and discussion are based only on the Armington demand models.

CHAPTER III

RESULTS AND DISCUSSION[13]

This section contains the results of the parameters and elasticity estimates for the U.S., EU and Japanese import demand, US domestic demand and the supply equations for each of those regions. The US and EU demand for imported shrimp are estimated using two different frameworks, the LA/AIDS framework and the Armington model.

3.1 Import Demand Estimates

3.1.1. Results Associated With the AIDS/LAIDS Model

The LA/AIDS demand system for United States and European Union were estimated twice, deleting the Central American equation for U.S. and the Rest of the World equation for EU once, and then dropping the South American equation for US and South American equation for EU the second time. This was done to avoid singularity in the full covariance matrix. The supply equations were separately estimated, with the same endogenous and exogenous variables. In accordance to Thompson (2004), expenditure equations were also included in the system and estimated simultaneously. The following estimates and elasticities were estimated with the expenditure equations in the system.

Parameter estimates for the U.S. import demand equations under the AIDS framework are presented in Table 3.1. The parameters on prices associated with each of the equations are positive except for the price on the same region. The coefficients on the expenditure term are all positive except that for South America. This implies that Asian

[13] As noted, cultured and wild shrimp production by region are provided by the FAO only on an annual basis and certain assumptions were employed to convert the annual figures to quarterly figures. Comparable results to those presented in this section but assuming constant quarterly production of cultured and wild shrimp within a given year are presented in Appendix A.

and Central American shrimp are conditionally expenditure elastic while the South American shrimp is conditionally expenditure inelastic.

Table 3.1: Parameter estimates for US import demand

	γ	β	λ	δ
Asia		0.0532 (0.103)	0.0069* (0.002)	δ_1= -0.0079 (0.051)
Vs Asia	-0.7253* (0.183)			
Vs CA	0.1385 (0.069)			δ_2= - 0.0262 (0.054)
Vs SA	0.5867* (0.178)			δ_3= 0.0497 (0.027)
Central America		0.0212 (0.047)	-0.0001 (0.0008)	δ_1= - 0.0998* (0.022)
Vs Asia	0.1385 (0.069)			
Vs CA	-0.2179* (0.045)			δ_2= - 0.1700* (0.023)
Vs SA	0.0794 (0.075)			δ_3= - 0.1238* (0.012)
South America		-0.0320 (0.088)	-0.0067* (0.002)	δ_1= 0.1078* (0.043)
Vs Asia	0.5867* (0.178)			
Vs CA	0.0794 (0.075)			δ_2= 0.1962* (0.047)
Vs SA	-0.6661* (0.205)			δ_3= 0.0740* (0.024)

γ = coefficient on prices, β = coefficient on expenditure,
λ = coefficient on trend, δ = coefficient on dummies.
* indicates statistically significant at 5% level of significance

Parameter estimates associated with the EU import demand equations are presented in Table 3.2. The coefficients on the expenditure term are all negative except that for South America. This implies that South American shrimp is conditionally expenditure elastic while the Asian and Rest of the World shrimp is conditionally expenditure inelastic.

Table 3.2: Parameter estimates for EU Import demand

	γ	β	λ	δ
Asia		-0.2181* (0.062)	0.0026* (0.0007)	δ_1= -0.0559 (0.031)
Vs Asia	0.1643 (0.051)			δ_2= - 0.0729* (0.021)
Vs SA	-0.0578 (0.045)			
Vs ROW	-0.1065* (0.022)			δ_3= - 0.0496* (0.018)
South America		0.2857* (0.046)	-0.0039* (0.0005)	δ_1= 0.0859* (0.021)
Vs Asia	-0.0578 (0.045)			δ_2= 0.0591* (0.014)
Vs SA	0.1384 (0.048)			
Vs ROW	-0.0806* (0.015)			δ_3= 0.0239 (0.012)
Rest of the World		-0.0676 * (0.031)	-0.0013* (0.0004)	δ_1= -0.0299 (0.016)
Vs Asia	-0.1065* (0.022)			δ_2= 0.0138 (0.011)
Vs SA	-0.0806* (0.015)			
Vs ROW	0.1871* (0.014)			δ_3= 0.0257* (0.009)

γ = coefficient on prices, β = coefficient on expenditure,
λ = coefficient on trend, δ = coefficient on dummies.
* indicates statistically significant at 5% level of significance

Compensated and uncompensated expenditure, own price and cross price elasticities are calculated using Chalfant's and Slutsky's formulae. The marginal shares, expenditure elasticities and own-price elasticities associated with the U.S. and E.U. shrimp import models are presented in Table 3.3. As indicated a large proportion of the estimated expenditure elasticities (two out of the three for the United States and all three for the European Union) are significant at the 95% level. Similarly, all of the estimated uncompensated own-price elasticities associated with the U.S. import demand system were found to be statistically significant while two of the three uncompensated own-price elasticities associated with the E.U. import demand system were found to be statistically significant

Table 3.3: Expenditure Elasticity, Marginal Share and Own-Price Elasticity for US and EU Imports

Source Region	Expenditure Elasticity	Marginal Share	Own-Price Elasticity	
			Cournot (Uncompensated)	Slutsky (Compensated)
US Imports from:				
Asia	1.099* (0.19)	0.587* (0.10)	-2.304* (0.41)	-1.823* (0.34)
South America	0.823 (0.48)	0.149 (0.08)	-4.705* (1.11)	-4.492* (1.13)
Central America	0.858* (0.31)	0.128* (0.04)	-2.477* (0.28)	-2.306* (0.30)
EU Imports from:				
Asia	0.424* (0.16)	0.161* (0.06)	-0.784* (0.11)	-0.187 (0.13)
South America	2.614* (0.26)	0.462* (0.04)	0.068 (0.30)	-0.040 (0.27)
Rest of the World	0.847* (0.07)	0.376* (0.03)	-0.645* (0.05)	-0.134* (0.03)

***** indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

All conditional expenditure elasticities for the United States and the European Union are positive. The results suggest that a 10% increase in total US expenditures on imported shrimp will result in an increase in demand for Asian product by about 11% compared to about an 8% increase in demand for the South America and Central American product. For the European Union, the results suggest that for every 10% increase in total EU expenditures on imported shrimp, demand for South American product will increase by 26.1% while that for Asian and the Rest of the World shrimp will go up by 4.2% and 8.4% respectively.

With the exception of the uncompensated elasticity for EU imports from South America (which is statistically insignificant), all compensated and uncompensated own-price elasticities are negative. For the United States, imported shrimp from all three exporting regions are highly price elastic (and statistically significant), with the South American product being the most price elastic and Asian shrimp being the least price elastic. The relatively small difference between the compensated and uncompensated own-price elasticity indicates relative expenditure insensitivity associated with U.S. demand for imported shrimp. For the European Union, Asian product appears to be the most price elastic, followed by the Rest of the World The own-price elasticity associated with American exports to the European Union was not found to be statistically significant.

Table 3.4: Uncompensated and Compensated cross price elasticity for US shrimp imports

Region	Asia	South America	Central America
		Slutsky (Compensated)	
Asia		1.280* (0.33)	0.409* (0.13)
South America	3.769* (0.98)		0.587 (0.41)
Central America	1.459* (0.46)	0.711 (0.50)	
		Cournot (Uncompensated)	
Asia		1.080* (0.35)	0.244 (0.14)
South America	3.33* (0.88)		0.464 (0.44)
Central America	1.001* (0.41)	0.538 (0.51)	

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

The compensated and uncompensated cross-price elasticities for US shrimp demand from the three exporting regions are presented in Table 3.4. All of the compensated and uncompensated cross-price elasiticities for US shrimp imports, by region, are positive, implying that imports from all regions are substitutes for one another. However, results also suggest that the cross-price elasticity of Central American product with respect to South American product (and vice versa) are statistically insignificant.

Asian shrimp is price elastic with respect to South American shrimp and price inelastic with respect to the Central American shrimp. The analysis indicates that a 10% increase in the price of Asian shrimp will increase the compensated (uncompensated) demand for South American shrimp by 12.8% (10.8%), whereas the compensated (uncompensated) demand for Central American shrimp will increase by only 4.0% (2.4%). South American shrimp is highly price elastic with respect to Asian shrimp and price inelastic with respect to Central American shrimp. Specifically, results suggest that a 10% increase in the price of South American shrimp will increase the compensated (uncompensated) demand for Asian shrimp by 37.7% (33.3%) whereas the compensated (uncompensated) demand for Central American shrimp will increase by only 5.8% (4.6%). Central American shrimp is also price elastic with respect to Asian shrimp and price inelastic with respect to South American shrimp. A 10% increase in the price of Central American shrimp will lead to a 14.6% (10.01%) increase in the compensated (uncompensated) demand of Asian shrimp and the same will lead to only 7.11% (5.38%) increase in the compensated (uncompensated) demand of South American shrimp.

As indicated by the information presented in Table 3.5, all of the compensated cross-price elasticities for the European Union are positive except Rest of the World vs. South America (which is statistically insignificant) and South America vs. Rest of the World (which is also statistically insignificant). All of the cross-price elasticities for the European market are less than one; implying that they are all relatively inelastic.

Table 3.5: Uncompensated and Compensated cross price elasticity for EU shrimp imports

Region	Asia	South America	Rest of the World
		Slutsky (Compensated)	
Asia		0.024 (0.11)	0.162* (0.06)
South America	0.052 (0.25)		-0.112 (0.08)
Rest of the World	0.139* (0.05)	-0.004 (0.03)	
		Cournot (Uncompensated)	
Asia		0.050 (0.10)	-0.025 (0.08)
South America	-0.939* (0.33)		-1.172* (0.15)
Rest of the World	-0.182 (0.06)	-0.154* (0.03)	

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

3.1.2 US Import Demand Associated With the Armington Model

The US demand for imported shrimp was also modeled using the Armington model. The total US demand for imported shrimp is divided into demand for Asian product, South American product, and Central American product. Presence of serial correlation was mitigated using the %ar macro in SAS/ETS. Parameter estimates associated with the Armington model are given in Table 3.6.

Table 3.6: Parameter Estimates for US demand using the Armington Model.

Import Region	Intercept	Price Ratio	Lagged Share	Trend	dum1	dum2	dum3	yd
Asia	-0.4177* (0.071)	-0.9321* (0.171)	0.5387* (0.078)	0.002* (0.0006)	0.0049 (0.029)	-0.0287 (0.024)	0.052 (0.02)	0.0283 (0.027)
Central America	-0.3419* (0.171)	-0.9321* (0.171)	0.5387* (0.078)	-0.0005 (0.001)	-0.7028* (0.067)	-0.793* (0.056)	-0.123 (0.08)	-0.1369 (0.070)
South America	-0.5510* (0.158)	-0.9321* (0.171)	0.5387* (0.078)	-0.010* (0.002)	0.7719* (0.070)	0.795* (0.072)	0.199* (0.074)	-0.0361 (0.079)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

The coefficients on the lagged share of each market and the price ratio are statistically significant at 5% level of significance and are of the expected sign. This suggests that a change in the price ratio for shrimp from one region over others, and also change in market share from the previous quarter will have a significant impact on the current market share. The trend variable for market share of Asian shrimp is positive and significant and that for South American shrimp is negative and significant. This suggests that the share of Asian imports in the US market is increasing while that of South American imports is declining. The dummy variables included to allow for the quarterly variation in import demand are, with the exception of Asian imports, generally statistically significant. The dummy variable included in the model to account for post September 11 effects on shrimp demand is statistically insignificant, suggesting that the events of September 11, 2001 did not significantly alter the composition of US shrimp imports.

Short-run and long-run substitution (market share) elasticity for shrimp imported from the three regions is given by the coefficient on the price ratios. The long-run elasticity is obtained by subtracting the coefficient on the lagged market share from 1 and dividing the short run elasticity by the resultant figure. The short run and long run substitution elasticities for the US shrimp market are given in Table 3.7.

Table 3.7: Short run and Long run Substitution (Market Share) Elasticities for US Shrimp Imports.

Short Run	**Long Run**
- 0.9321* (0.171)	- 2.0205* (0.307)

***** indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

As indicated by the information presented in Table 3.7, a one percent increase in the relative price ratio of any of the importing region will lead to a 0.93% decline in the market share of that region in the short run and a decline of 2.02% in the long run. These results also indicate that substitution possibilities between shrimp from different regions is indeed low, which suggests they are imperfect substitutes.

3.1.3 Japanese Import Demand from Asia

Parameter estimates associated with the Japanese import demand equation are given in Table 3.8. All of the parameters have expected signs and, with the exception of income, all are statistically significant at the 5% level of significance.

Table 3.8: Parameter Estimates for Japanese Import Demand

Price	Inventories	Income	Trend	Dummy 1	Dummy 2	Dummy 3
- 0.2187* (0.071)	-0.5032* (0.197)	0.0002 (0.0002)	-1.3582* (0.314)	-42.683* (7.30)	-35.747* (6.65)	-21.049* (6.15)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

For every one-hundred yen increase in the price of shrimp exported from Asia to Japan, the import quantity demanded declines by 21.87 million pounds, *ceteris paribus*. Similarly, with every million pound increase in beginning inventories, the quantity of Asian imports demanded declines by approximately one-half million pounds. The trend variable suggests that import demand for Asian shrimp in Japan is declining by 1.36 million pounds per year. The dummy variable shows that the import demand is highest on the fourth quarter, followed by third, second and lastly, the first quarter.

3.1.4 US Demand for Gulf of Mexico Shrimp

Parameter estimates associated with the Gulf of Mexico inverse dockside demand equation are given in Table 3.9.

Most of the parameters are statistically significant at 95% level of significance and the signs associated with the estimated parameters generally agree with *a priori* expectations. The import prices from the three exporting regions all exhibit positive signs, signifying that an increase (decrease) in import prices leads to an increase (decrease) in the Gulf of Mexico dockside. Because a change in one import price will result in a change in other import prices, one is unable to ascertain direct price flexibilities associated with changes in any of the individual export prices (see Buse, 1958, for details).

Table 3.9: Parameter Estimates for Gulf on Mexico Shrimp demand Equation.

Asian Price	C. Am. Price	S. Am. Price	Qty	Avg. No. of Shrimp per lb	Pct. White	Pct. Heads-On	US Inventory	Dummy 1	Dummy 2	Dummy 3
0.2231* (0.071)	0.3582* (0.103)	0.4641* (0.089)	-0.1744* (0.051)	-0.3851* (0.107)	-0.1084* (0.030)	0.0237 (0.092)	-0.0544 (0.071)	-0.0209 (0.075)	0.0739 (0.072)	0.1019 (0.035)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Results also suggest that the dockside price is inversely related to the quantity harvested. Specifically, results suggest that a 10% increase (decrease) in the harvest quantity will result in a 1.7% decline (increase) in dockside price, *ceteris paribus*. Similarly, a 10% increase in the average number of shrimp per pound was found to result in a 3.9% decrease in the dockside price, holding all other factors constant. Results also suggest that increasing the percentage of white shrimp in the catch composition results in a reduction in dockside price. Finally, the proportion of catch comprised of heads-on shrimp was not found to statistically influence the dockside price (which is expressed on a price per pound of headless shrimp).

3.2 Export Supply Estimates

3.2.1 Asian Export Supply

Parameter estimates for the Asian export supply to the United States are given in Table 3.10. All of the parameter estimates have expected signs and are statistically significant at 95% level of significance.

Results suggest that for every dollar increase in the Asian export price to the United States, the quantity supplied is expected to increase by 17.11 million pounds, *ceteris paribus*.[14] Similarly, with every dollar increase in Asian export price to Japan, the quantity supplied to United States will decline by 21.02 million pounds, holding all other variables constant. Parameter estimates associated with the Japanese and the US import prices are very close in magnitude but of opposite signs, which suggests that a unit change in price in each market will have an effect nearly similar in magnitude but in opposite direction in total U.S. imports from Asia.

Table 3.10: Parameter estimates for Asian Export Supply to the United States

US import price	Japanese import price	Total Asian export	Dummy 1	Dummy 2	Dummy 3
17.111* (3.17)	-21.025* (3.06)	0.825* (0.02)	27.039* (4.32)	19.944* (4.35)	9.921* (3.80)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table 3.11 contains the parameter estimates for the Asian export supply to Japan. All of the estimates have the expected signs and are statistically significant at 95% level of significance except the total Asian export.

Table 3.11: Parameter estimates for Asian Export Supply to Japan

US import price	Japanese import price	Total Asian export	Dummy 1	Dummy 2	Dummy 3
-27.279 * (3.85)	27.293 * (4.40)	-0.042 (0.03)	-27.525 * (5.54)	-22.331 * (5.57)	-4.242 (4.87)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

For every dollar increase in the US import prices for Asian shrimp, quantity supplied to Japan will go down by 27.27 million pounds and for every dollar increase in the Japanese import price, it will go up by 27.29 million pounds, *cetaris paribus.* This

[14] All of these estimates should be considered partial in nature because a change in one price (e.g., the U.S. price will subsequently result in a change in price in the competing region (e.g., Japan).

shows that the Asian exports are indifferent between supplying to Japan or the United States, and price change in each market will have equal but opposite effect on the quantity supplied to Japan.

Overall, the large and statistically signficant parameter estimate associated with Total Asian Export in the U.S. equation (i.e., parameter estimate of 0.825 and standard error of 0.02) and the statistically insignificant parameter estimate associated with Total Asian Export in the Japanese equation (i.e, -0.042 and standard error of 0.03) is consistent with observed patterns. Specifically, exports from Asia to the United States have increased significantly since 1990 while exports from Asia to Japan have fallen (see Chapter 1). Since there is competition for the Asian product between the U.S. and Japanese markets based on price differentials in the two markets, the increasing U.S. share vis-à-vis Japanese share must reflect changes in relative demand in the two regions.

Parameter estimates for the overall Asian supply are presented in Table 3.12. All the parameter estimates carry correct signs and are statistically significant at 95% level of significance.

All other factors held constant, a one-million pound increase in Asian cultured production (expressed on a live weight basis which translates to a 630 thousand pound increase when converted to a headless weight) was found to result in an increase of 347,thousand pounds in total shrimp exports (product weight) from Asia. Similarly, holding all other factors constant, a one-million pound increase in the wild Asian production was found to result in a 42 thousand pound increase in Asian shrimp exports. The greater impact associated with an increase in cultured production vis-à-vis wild production is consistent with the general observation that most product exported from Asia is of cultured origin.

Table 3.12: Parameter estimates for Total Asian Export Supply

Cultured Production	Wild Harvest	Aggregated Asian Income	Dummy 1	Dummy 2	Dummy 3
0.347* (0.01)	0.042* (0.02)	-0.975* (0.18)	-23.625* (6.41)	-23.623* (6.47)	-12.063* (5.48)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

3.2.2 South American Export Supply

Table 3.13 presents the parameter estimates for South American export supply to the United States. All the parameter estimates are statistically significant at 95% level of significance and exhibit the theoretically correct signs. Holding all other factors constant, a one-dollar increase in the South American export price to the United States was estimated to result in an increase of 5.45 million pounds in quantity exported to the United States.[15] Conversely, a one-dollar increase in South American export price to the European Union was found to result in a decrease of 4.18 million pounds in the South American export supply to the US. Holding the U.S. and EU prices constant, a one-million pound increase in total South American exports (expressed on a headless weight which translates to 630 thousand pounds of heads-off product) results in exports to United States increasing by 401 thousand pounds.

Table3.13: Parameter estimates for South American Export Supply to the United States

US Price	EU Price	Total Exports	Dummy 1	Dummy 2	Dummy 3
5.450* (1.85)	-4.181* (2.65)	0.401* (0.06)	12.793* (2.52)	13.028* (2.28)	8.573* (2.26)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

[15] As with the Asian supply equations, this estimate should be considered partial in nature given the fact that a change in the export price to the United States would result in a change in the export price to the European Union.

Parameter estimates for the total South American export supply equation are presented in Table 3.14 The parameter for South American production is highly significant and exhibits the correct sign. It suggests that for every million pound increase in the cultured production in South America, total exports will increase by an estimated 880 thousand pounds. This implies that virtually all of the South American cultured shrimp is exported.[16]

Table 3.14: Parameter estimates for Total South American Export Supply

Cultured Production	Dummy 1	Dummy 2	Dummy 3
0.880* (0.07)	-10.507* (5.13)	-3.187 (5.11)	1.016 (5.09)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

3.2.3 Central American Export Supply to the United States

Table 3.15 contains the parameter estimates for Central American export supply equation. All the parameters have the expected signs and most are statistically significant.

Table 3.15: Parameter estimates for Central American Export Supply to the United States

US Import Price	Cultured Production	Wild Harvest	Aggregate Income	Dummy 1	Dummy 2	Dummy 3
0.661 * (0.18)	0.431 * (0.11)	0.567* (0.10)	-0.465 (0.32)	1.754 (5.19)	-1.747 (5.63)	9.815* (4.41)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Holding all other factors constant, the results suggest that a one-dollar increase in the Central American export price will lead to an increase in U.S. imports of 661

[16] This high estimate is somewhat disturbing because it implies that total exports will increase by 880 thousand pounds for every 630 thousand pound increase in cultured shrimp production (converted to a headless weight basis). This implausible finding may reflect underreporting of cultured shrimp production in Ecuador. Specifically, examination of the Ecuadorian export data to the U.S. and EU with FAO figures of cultured shrimp production in the country indicates that exports generally exceed total production.

thousand pounds.[17] Similarly, keeping the export price, income and wild harvest constant, a million pound increase in cultured production (live weight) will lead to a 431 thousand pound increase in exports to the U.S. market. Holding price, cultured production and income constant, a million pound increase in the wild harvest (heads on which translates to a 630 thousand pound increase of headless product) will lead to a 567 thousand pound increase in Central American supply to the Unites States. This finding is consistent with the observation that most of the wild product is directed to the U.S. market.

3.3 Reduced Form Equations and Results

To obtain the reduced form equations in terms of import prices, the import demand equations and the export supply equations from each region were solved separately. The demand equations used to obtain the reduced form equations are from the Armington model.[18] For the Asian market, the following structural equations were used to estimate the reduced form equations: (a) U.S. import demand from Asia (based on the Armington model), (b) Japanese import demand from Asia, (c) Asian export supply to the United States. (d) Asian export supply to Japan, and (e) the overall Asian Supply equation. The European Union, whose import is very small compared to that of the US and Japan, was not included in the system because it acts like a residual market, which takes in whatever is left behind after US and Japan imports. Thus, the European import price was treated as an exogenous variable in the reduced form equation.

[17] This figure is relatively small but of the expected sign and statistically significant. The finding of a relatively small impact associated with a relatively large change in price is not unexpected given that the majority of the Central American product has historically been shipped to the United States with at-home consumption being relatively limited.
[18] As previously noted, an attempt was made to derive the reduced form equations based on the AIDS demand models but no solution could be found.

For the South American market, the following structural equations were used to derive the reduced form equations: (a) the U.S. import demand from South America (based on the Armington model), (b) South American export supply to the United States, and (c) the overall South American supply equation. The European market, again, is small compared to the US market. Hence, the European import prices were treated as exogenous.

For Central American market, US import demand from Central America and the Central American export supply to the US were used to get the reduced from equation in terms of US import price from Central America.

The demand and supply equations for each of the above described regions were solved for the prices and quantities using Mathematica to yield the reduced form equations. The resulting equations are presented in Appendix B.

The reduced form equations were used to generate a series of predicted US import prices from Asia, South America and Central America. These predicted prices were subsequently substituted into the dockside inverse demand equation to generate the predicted dockside price, by quarter. Figure 12 presents the actual dockside prices and the predicted dockside prices for the study period.

To analyze the effect of various exogenous factors on the Gulf of Mexico dockside shrimp prices, the reduced form equations (specified in terms of respective import prices as a function of all exogenous variables included in the analysis) were substituted into the dockside price equation and the elasticity associated with each of the exogenous variables was estimated (Table 3.16)[19].

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[19] As previously noted, wild and cultured shrimp production by region is available only on an annual basis and certain assumptions were employed to convert these annual figures to quarterly figures. Appendix C

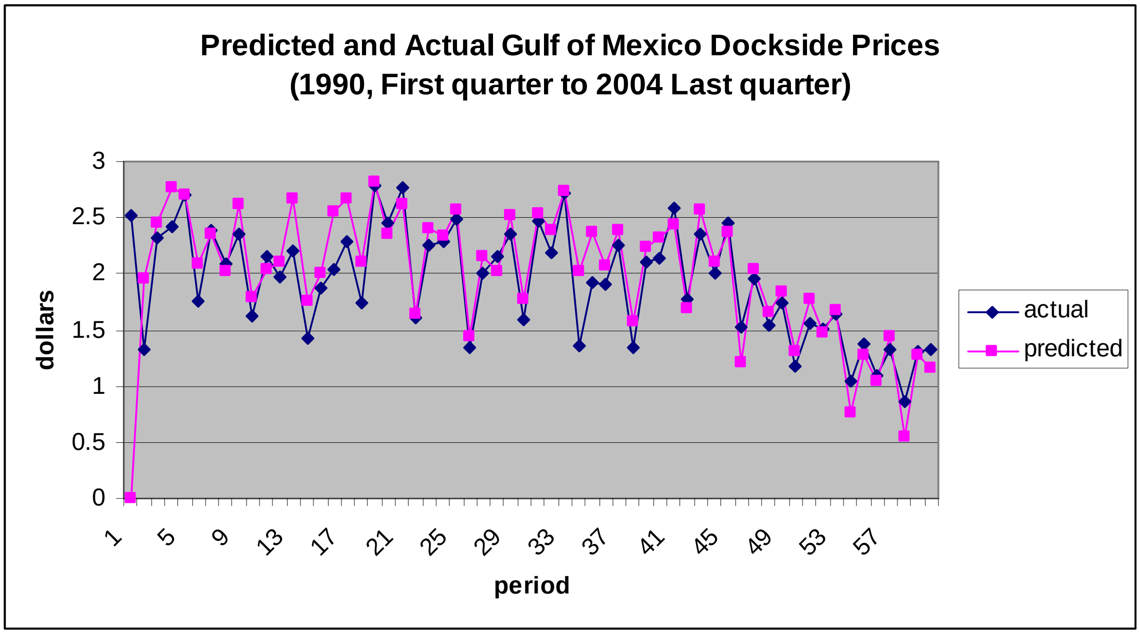

Figure 3.1: Predicted and Actual Gulf of Mexico Dockside Prices

As expected, an increase in shrimp production (either cultured or wild) from any of the three regions was found to exert a negative influence on the Gulf of Mexico dockside price. A 10% increase in the Asian cultured and wild production was found to result in a 3.5% and 1.5% decline in dockside price, respectively. This concurs with the fact that Asia is the largest exporter to the United States and majority of its export is cultured shrimp. Hence, Asian cultured production has the largest effect on the dockside price. Similarly, 10% percent increase in Central American cultured and wild production was estimated to result in a 1.0% and 2.7% decline in dockside price, respectively. Similar to that found for Central America, a 10% increase in South American cultured production was estimated to result in a decline in dockside price equal to 2.3%.

Increases in incomes of the producing regions and Japan (the second largest shrimp importer after the United States) have a positive effect on the dockside price. This

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provides estimates comparable to those presented in Table 3.16 under the assumption that quarterly production of shrimp (both wild and cultured) is constant within a year but allowing production to change by year. A comparison of the information contained in Table 3.16 with that in Appendix C suggests that with a few notable exceptions (particularly overall Asian income), elasticity estimates are relatively stable.

is expected, since increased income in the producing regions expands domestic demand and hence results in a decrease in export supply, *ceteris paribus*. Similarly, increased income in Japan results in an increased demand for the Asian product in Japan, hence diverting product from the U.S. market to the Japanese market more of the Asian shrimp into Japan.. Overall Asian income and Japanese income have almost equal effect in the dockside price; a 10% increase in either resulting in about 1.1% increase in the Gulf of Mexico dockside price. An increase in the Central American income has a slightly larger on the Gulf of Mexico dockside price vis-à-vis Asian income. A 10% increase in Central American income was found to result in a 1.5% increase in the dockside price.

Table 3.16: Estimated change in the Gulf of Mexico dockside price resulting from a one percent change in selected exogenous variables in the reduced form equations.

Components of Import Prices	**Flexibility**
Asian Cultured Production	-0.34941
Asian Wild Production	-0.14588
Central American Cultured Production	-0.10356
Central American Wild Production	-0.26983
South American Cultured Production	-0.22598
Overall Asian Income	0.11799
Japanese Income	0.11594
Central American Income	0.15435
Weighted Import Price	0.28450
South American Export Price to EU	0.20091
Lagged Import From Asia	-0.14587
Lagged Imports From Central America	0.15230
Lagged Imports From South America	0.15700

Weighted import price from the three major exporters to the US has positive effect on dockside price. This is also expected, since increased price of imported shrimp will encourage consumers to look for alternative sources, which will favor domestic price. A one percent increase in the overall import price increase the dockside price by 0.28%. South American export price to the European Union also has a positive effect on the dockside price, which is also expected. Increased price in EU drives more of the South American exports to the EU, hence lowering the quantity imported to US. This favors the price of domestic shrimp. One percent increase in export price to EU increases the dockside price by 0.20%.

CHAPTER IV

SUMMARY AND CONCLUSIONS

The world shrimp market has expanded significantly since the mid-1980s as a result of expanding cultured activities; particularly in Asia and South America. Based on FAO data, 2004 shrimp exports were estimated to account for about 17% of the $71 billion world seafood export market. The increased world production of shrimp and concomitant expansion in the world export market has resulted in a decline in the world export price

For purposes of analysis, a set of import demand and export supply equations were estimated. Specifically, import demand equations were estimated for three countries (regions) that account for the majority of shrimp imports – the United States, Japan, and the European Union. Similarly, export supply equations, were developed for the three primary warm-water shrimp producing regions – Asia, South America, and Central America. In order to examine supply from each region to the primary consuming regions, another set of allocation equations (with the exception of Central America) were added to the system. Finally, an inverse demand equation associated with U.S. Gulf of Mexico shrimp production was estimated. Since many of the export/import prices were assumed to be endogenous, the demand and supply systems were estimated via an iterative three-stage least squares procedure.

The majority of the results conform to theoretical expectations. Almost all of the parameter estimates in all of the demand equations were of the expected sign and are statistically significant. All of the compensated and uncompensated own demand price elasticities were found to be negative and statistically significant while most of the cross price elasticities were positive. The parameter signs associated with prices in the export equations were all also of the expected signs and were generally statistically significant.

The export supply equations indicate that an increase in the Japanese price vis-à-vis the U.S. price will divert a significant quantity of shrimp from the U.S. market to the Japanese market while the converse (i.e., an increase in the U.S. price vis-à-vis the Japanese price) will result in increased exports of the Asian product to the U.S. market at the expense of the Japanese market. Similarly, an increase in the U.S. price vis-à-vis the European price was found to result in significant shifts of the South American product to the U.S. market at the expense of the European market. Finally, increased cultured shrimp production from all of the primary exporting regions (i.e., Asia, South America, and Central America) was found to result in a significant increase in the amount of shrimp being placed on the world market.

The effect of import prices, or more specifically, those factors determining import prices, were calculated as elasticities of the respective factors with respect to the Gulf of Mexico dockside price. Most of the elasticities concur with theoretical expectations. Increases in production in each of the three major producing regions -both captured and cultured,- were found to negatively impact the Gulf of Mexico dockside price. Overall, an increase in Asian production was determined to have the largest effect on the U.S .Gulf of Mexico dockside price. These results, as expected, indicate that the increasing import base has had a detrimental effect on the Gulf of Mexico dockside shrimp price. Asian cultured production in particular has had a large impact, with every one- percent increase leading to 0.35 percent decrease in the dockside price.

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APPENDIX A

ESTIMATION OF DEMAND AND SUPPLY ASSUMING NO VARIATION IN QUARTERLY PRODUCTION

In this part, quarterly variation in production is neglected and it is assumed that the production remains uniform throughout the year. The AIDS model for demand of imported shrimp in the US and the EU and the supply equations for the three major supply regions are re-estimated under this assumption. The estimated demand parameters are reported on the tables below in tables A.1 and A.2 for the US and the EU, respectively..

Various elasticities of demand estimated from the demand equation, along with the marginal share and expenditure elasticities also do not defer significantly form the original estimates. The estimated elasticites for the United States and the European Union are reported in the tables A.3 through A.5. Similarly, supply equations estimated with constant quarterly production did not vary much in the parameters from the original estimations. The estimated parameters are reported in the tables A.6 through A.11.

Table A.1: Parameter estimates for US import demand with assumed constant quarterly production

	γ	β	λ	δ
Asia		0.748 (0.097)	0.0061* (0.002)	δ_1= -0.0034 (0.047)
Vs Asia	-0.6671* (0.172)			δ_2= - 0.0120 (0.050)
Vs CA	0.1505* (0.060)			
Vs SA	0.5166* (0.166)			δ_3= 0.0551 (0.026)
Central America		0.0094 (0.047)	-0.0003 (0.0008)	δ_1= - 0.0968* (0.022)
Vs Asia	0.1505* (0.060)			δ_2= - 0.1644* (0.023)
Vs CA	-0.2165* (0.045)			
Vs SA	0.0657 (0.073)			δ_3= - 0.1226* (0.012)
South America		-0.0147 (0.047)	-0.0058* (0.002)	δ_1= - 0.0936* (0.039)
Vs Asia	0.5166* (0.166)			δ_2= - 0.1787* (0.043)
Vs CA	0.0657 (0.073)			
Vs SA	-0.5823* (0.195)			δ_3= - 0.0675* (0.02

γ = coefficient on prices, β = coefficient on expenditure,
λ = coefficient on trend, δ = coefficient on dummies.
* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.2: Parameter estimates for EU Import demand with assumed constant quarterly production

	γ	β	λ	δ
Asia		-0.1244* (0.059)	0.0015* (0.0007)	δ_1= -0.0085 (0.027)
Vs Asia	0.0504 (0.053)			δ_2= - 0.0457* (0.018)
Vs SA	0.0183 (0.044)			
Vs ROW	-0.0688* (0.024)			δ_3= - 0.0295 (0.015)
South America		0.2126* (0.043)	-0.0030 (0.0004)	δ_1= 0.0504* (0.018)
Vs Asia	0.0183 (0.044)			δ_2= 0.0390* (0.012)
Vs SA	0.0826 (0.044)			
Vs ROW	-0.1026* (0.015)			δ_3= 0.0088* (0.010)
Rest of the World		-0.0917 * (0.031)	-0.0016* (0.0004)	δ_1= -0.0418* (0.030)
Vs Asia	-0.0688* (0.024)			δ_2= 0.0066 (0.010)
Vs SA	-0.1026* (0.015)			
Vs ROW	0.1714* (0.015)			δ_3= 0.0207* (0.008)

γ = coefficient on prices, β = coefficient on expenditure,
λ = coefficient on trend, δ = coefficient on dummies.
* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.3: Expenditure Elasticity, Marginal Share and Own-Price Elasticity for US and EU Imports, assuming constant quarterly production

Source Region	**Expenditure Elasticity**	**Marginal Share**	**Own-Price Elasticity**	
			Cournot (Uncompensated)	**Slutsky (Compensated)**
US Imports from:				
Asia	1.140* (0.18)	0.608* (0.09)	-2.174* (0.38)	-1.715* (0.32)
South America	0.672 (0.44)	0.121 (0.08)	-4.271* (1.14)	-4.030* (1.07)
Central America	0.901* (0.31)	0.135* (0.04)	-2.461* (0.28)	-2.297* (0.30)
EU Imports from:				
Asia	0.671* (0.15)	0.254* (0.05)	-1.0122* (0.11)	-0.487* (0.14)
South America	2.201* (0.24)	0.389* (0.04)	0.446 (0.37)	-0.355 (0.25)
Rest of the World	0.793* (0.06)	0.352* (0.03)	-0.710* (0.05)	-0.169* (0.03)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.4: Uncompensated and Compensated cross price elasticity for US shrimp imports, assuming constant quarterly production

Region	**Asia**	**South America**	**Central America**
	Slutsky (Compensated)		
Asia		1.148* (0.31)	0.431* (0.12)
South America	3.383* (0.91)		0.512 (0.40)
Central America	1.539* (0.45)	0.620 (0.49)	
	Cournot (Uncompensated)		
Asia		0.941* (0.32)	0.260 (0.14)
South America	3.024* (0.83)		0.411 (0.43)
Central America	1.060* (0.40)	0.444 (0.49)	

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.5: Uncompensated and Compensated cross price elasticity for EU shrimp imports, assuming constant quarterly production

Region	Asia	South America	Rest of the World
		Slutsky (Compensated)	
Asia		0.225 (0.11)	0.262* (0.06)
South America	0.482 (0.25)		-0.136 (0.08)
Rest of the World	0.215* (0.05)	-0.041 (0.03)	
		Cournot (Uncompensated)	
Asia		0.106 (0.10)	-0.035 (0.08)
South America	-0.376 (0.33)		-1.079* (0.13)
Rest of the World	-0.076 (0.07)	-0.194* (0.03)	

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.6: Parameter estimates for Asian Export Supply to US, assuming constant quarterly productions

US import price	Japanese import price	Total Asian export	Dummy 1	Dummy 2	Dummy 3
16.247* (3.17)	-19.800* (3.75)	0.829* (0.02)	27.612* (4.35)	20.564* (4.38)	10.433* (3.82)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.7: Parameter estimates for Asian Export Supply to Japan, assuming constant quarterly productions

US import price	Japanese import price	Total Asian export	Dummy 1	Dummy 2	Dummy 3
-24.900 * (3.91)	24.753 * (4.49)	-0.058 (0.03)	-29.267 * (5.70)	-24.253 * (5.72)	-5.654 (4.981)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.8: Parameter estimates for Total Asian Export Supply, assuming constant quarterly productions

Cultured Production	Wild Harvest	Aggregated Asian Income	Dummy 1	Dummy 2	Dummy 3
0.356 * (0.02)	0.022 * (0.02)	-0.913* (0.17)	-26.743 * (6.44)	-26.780 * (6.50)	-13.408* (5.50)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.9: Parameter estimates for South American Export Supply to the United States, assuming constant quarterly productions

US Price	EU Price	Total Exports	Dummy 1	Dummy 2	Dummy 3
5.689 * (1.83)	-4.650 * (2.60)	0.400* (0.06)	12.785* (2.53)	12.984* (2.29)	8.525* (2.28)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.10: Parameter estimates for Total South American Export Supply, assuming constant quarterly productions

Cultured Production	Dummy 1	Dummy 2	Dummy 3
0.866* (0.07)	-10.629* (5.11)	-3.090 (5.10)	0.975 (5.07)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

Table A.11: Parameter estimates for Central American Export Supply to the United States, assuming constant quarterly productions

US Import Price	Cultured Production	Wild Harvest	Aggregate Income	Dummy 1	Dummy 2	Dummy 3
0.462 * (0.21)	-0.0146 (0.17)	0.742* (0.13)	0.618 (0.48)	-30.718 * (2.19)	-36.459 * (2.24)	- 17.61* (2.37)

* indicates statistically significant at 5% level of significance
values in parenthesis are standard errors

APPENDIX B

REDUCED FORM EQUATIONS

Following are the reduced form equations obtained by solving the respective demand and supply equations. The supply equations were expressed in double log form for ease of calculation.

1. Japanese Import Quantity (qfroa):

Log(qfroa) = dum1* jdd1 + dum2* jdd2 + dum3* jdd3 + jdi + jtr* t + jinv * log(injapan)+ jinc* Log((100* cjinco)/jcpi) + jop* Log((100* exrate)/jcpi) - jop* (((-(((-ausi) - dum1* sad1 - dum2* sad2 - dum3* sad3)/jpu)) - (aex1* (((-dum1)* soad1 - dum2* soad2 - dum3 * soad3 - soai - ap1* Log(acultq) - ap2* Log(awildq) - ainc* Log(inc_as))))/jpu - ((1/jpu)*((upu* (((-((((aex1*jop - aex1* jpj + aex3* jpu))* (((-dum1)* soad1 - dum2* soad2 - dum3* soad3 - soai - ap1* Log(acultq) - ap2*Log(awildq) - ainc* Log(inc_as)))) / ((-jop)* pr + jpj* pr + jpu* upj + jop* upu - jpj* upu))) + ((1/((-jop)* pr + jpj* pr + jpu* upj + jop*upu - jpj* upu))*((ausi* jop - ad1* dum1* jop - ad2* dum2* jop - ad3*dum3 * jop - inta* jop - ausi* jpj + ad1* dum1* jpj + ad2* dum2* jpj + ad3* dum3* jpj + inta* jpj + aeji* jpu - dum1* jdd1* jpu - dum2* jdd2* jpu - dum3* jdd3* jpu - jdi* jpu + dum1*jop* sad1 - dum1* jpj* sad1 + dum2* jop*sad2 - dum2* jpj* sad2 + dum3* jop* sad3 - dum3* jpj* sad3 + dum1* jpu*sajd1 + dum2* jpu* sajd2 + dum3* jpu*sajd3 - jpu* jtr* t - jop* t* ta + jpj* t* ta - jop* yda* ydum + jpj* yda*ydum - jinv* jpu* Log(injapan) – jinc * jpu * Log((100*cjinco)/jcpi) - jop* jpu* Log((100* exrate)/jcpi) - jop* lq* Log(lags) + jpj* lq* Log(lags) - jop* Log(totu) + jpj*Log(totu) + jop*pr*Log(wpr) - jpj* pr* Log(wpr))))))))) + ((1/jpu)*(((-ad1)* dum1 - ad2* dum2 - ad3* dum3 - inta - t* ta - yda* ydum - lq* Log(lags) - Log(totu) + pr* Log(wpr) + pr* (((-((((aex1* jop - aex1* jpj + aex3* jpu)) *(((-dum1)* soad1 - dum2* soad2 - dum3* soad3 – soai - ap1* Log(acultq) - ap2* Log(awildq) - ainc* Log(inc_as))))/((-jop)* pr + jpj* pr + jpu* upj + jop* upu - jpj* upu))) + ((ausi* jop - ad1* dum1* jop - ad2* dum2* jop - ad3* dum3* jop - inta* jop - ausi* jpj + ad1* dum1* jpj + ad2* dum2* jpj + ad3* dum3* jpj + inta* jpj + aeji* jpu - dum1* jdd1* jpu - dum2* jdd2*jpu - dum3* jdd3* jpu - jdi* jpu + dum1* jop* sad1 - dum1* jpj* sad1 + dum2* jop* sad2 - dum2* jpj*sad2 + dum3* jop* sad3 - dum3* jpj* sad3 + dum1* jpu* sajd1 + dum2* jpu* sajd2 + dum3* jpu* sajd3 - jpu*jtr* t - jop* t* ta + jpj* t* ta - jop* yda*ydum + jpj* yda* ydum - jinv* jpu* Log(injapan) - jinc* jpu*Log((100* cjinco)/jcpi) - jop* jpu* Log((100*exrate)/jcpi) – jop * lq * log(lags) + jpj* lq* log(lags) - jop*log(totu) + jpj * log(totu) + jop * pr * log(wpr) - jpj* pr*log(wpr)))/(((-jop)* pr + jpj * pr + jpu * upj + jop * upu - jpj* upu)))))))));

2. <u>Japanese Import Price:</u>

Log(cpjas) = ((-ausi) - dum1 *sad1 - dum2* sad2 - dum3* sad3)/jpu + (aex1* (((-
dum1)*soad1 - dum2* soad2 - dum3* soad3 – soai - ap1* log(acultq) - ap2*
log(awildq) - ainc*log(inc_as))))/jpu +((1/jpu)*((upu*(((-((((aex1* jop -
aex1* jpj + aex3* jpu)) * (((-dum1)*soad1 - dum2* soad2 - dum3* soad3 -
soai - ap1* log(acultq) - ap2*log(awildq) - ainc* log(inc_as))))/((-jop)* pr
+jpj* pr + jpu* upj + jop* upu - jpj* upu))) + ((1/((-jop)* pr + jpj*pr + jpu*
upj + jop* upu - jpj* upu))*((ausi* jop - ad1* dum1* jop - ad2* dum2* jop -
ad3* dum3* jop - inta* jop - ausi*jpj + ad1* dum1* jpj + ad2*dum2*jpj +
ad3* dum3* jpj + inta* jpj + aeji* jpu - dum1* jdd1* jpu - dum2* jdd2* jpu
- dum3* jdd3* jpu - jdi* jpu + dum1* jop* sad1 - dum1* jpj* sad1 + dum2*
jop* sad2 - dum2* jpj* sad2 + dum3* jop* sad3 - dum3* jpj* sad3 + dum1*
jpu*sajd1 + dum2* jpu* sajd2 + dum3* jpu* sajd3 - jpu* jtr*t - jop* t* ta +
jpj* t* ta - jop* yda* ydum + jpj* yda* ydum - jinv* jpu*log(injapan) -
jinc* jpu* log((100* cjinco)/jcpi) - jop* jpu* log((100*exrate)/jcpi) - jop*
lq* log(lags) + jpj* lq*log(lags) - jop* log(totu) + jpj* log(totu) + jop* pr*
log(wpr) - jpj* pr* log(wpr))))))))) -((1/jpu)*(((-ad1)* dum1 - ad2* dum2 -
ad3* dum3 - inta - t* ta - yda*ydum - lq* log(lags) - log(totu) + pr*
log(wpr) + pr* (((-((((aex1* jop - aex1* jpj + aex3* jpu))* (((-dum1)*soad1
- dum2* soad2 - dum3* soad3 - soai - ap1* log(acultq) - ap2* log(awildq) -
ainc* log(inc_as))))/((-jop)* pr + jpj* pr + jpu* upj + jop* upu - jpj* upu)))
+ ((1/((-jop)* pr + jpj* pr + jpu* upj + jop* upu - jpj* upu))*((ausi* jop -
ad1* dum1* jop - ad2* dum2* jop - ad3* dum3* jop - inta* jop - ausi* jpj +
ad1*dum1* jpj + ad2* dum2* jpj + ad3*dum3* jpj + inta* jpj + aeji*jpu -
dum1* jdd1* jpu - dum2* jdd2* jpu - dum3* jdd3*jpu - jdi* jpu + dum1*
jop* sad1 - dum1*jpj* sad1 + dum2* jop* sad2 - dum2* jpj* sad2 +
dum3*jop* sad3 - dum3* jpj* sad3 + dum1* jpu* sajd1 + dum2*jpu* sajd2
+ dum3* jpu* sajd3 - jpu* jtr* t - jop* t* ta + jpj* t* ta - jop* yda*ydum +
jpj* yda* ydum - jinv* jpu* log(injapan) - jinc* jpu * log((100*cjinco)/jcpi)
- jop*jpu* log((100* exrate)/jcpi) - jop* lq*log(lags) + jpj* lq* log(lags) -
jop* log(totu) + jpj* log(totu) + jop* pr* log(wpr) - jpj* pr* log(wpr)))))))));

3. <u>U.S. Import Quantity from Asia:</u>

Log(qia) = ad1*dum1 + ad2*dum2 + ad3*dum3 + inta + t*ta + yda*ydum +
lq*log(lags) + log(totu) - pr*log(wpr) - pr*(-(aex1*jop - aex1*jpj +
aex3*jpu))*(-dum1* soad1 - dum2*soad2 - dum3*soad3 - soai -
ap1*log(acultq) - ap2*log(awildq) - ainc*log(inc_as))/(-jop*pr + jpj* pr +
jpu*upj + jop*upu - jpj*upu) + (1/(-jop* pr + jpj* pr + jpu*upj + jop*upu -
jpj*upu))*(ausi*jop - ad1*dum1*jop - ad2*dum2*jop - ad3*dum3*jop -
inta*jop - ausi*jpj + ad1*dum1*jpj + ad2*dum2*jpj + ad3*dum3*jpj
+inta*jpj + aeji*jpu - dum1*jdd1*jpu - dum2*jdd2*jpu - dum3*jdd3*jpu -

jdi*jpu + dum1*jop*sad1 - dum1*jpj*sad1 + dum2*jop*sad2 - dum2*jpj*sad2 + dum3*jop*sad3 - dum3*jpj*sad3 + dum1*jpu*sajd1 + dum2*jpu*sajd2 + dum3*jpu* sajd3 - jpu*jtr*t - jop*t*ta + jpj*t*ta - jop*yda*ydum + jpj*yda*ydum - jinv*jpu*log(injapan) - jinc*jpu*log((**100***cjinco)/jcpi) - jop*jpu*log((**100***exrate)/jcpi) - jop* lq*log(lags) + jpj*lq*log(lags) - jop*log(totu) + jpj*log(totu) + jop*pr*log(wpr) - jpj*pr*log(wpr));

4. U.S. Import Price From Asia:

Log(cpia) = (**1**/(-jop*pr + jpj*pr + jpu*upj + jop*upu - jpj*upu))*(-ausi*jop + ad1*dum1*jop + ad2*dum2*jop + ad3*dum3*jop + inta*jop + ausi*jpj - ad1*dum1*jpj - ad2*dum2*jpj -ad3*dum3*jpj - inta*jpj - aeji*jpu + dum1*jdd1*jpu + dum2*jdd2*jpu + dum3*jdd3*jpu + jdi*jpu - dum1*jop*sad1 + dum1*jpj*sad1 - dum2*jop*sad2 - dum3*jop*sad3 + dum3*jpj*sad3 - dum1*jpu*sajd1 - dum2*jpu*sajd2 - dum3*jpu*sajd3 - aex1*dum1*jop*soad1 + aex1*dum1*jpj*soad1 - aex3 * dum1 * jpu * soad1 - aex1 * dum2 * jop * soad2 + aex1 * dum2 * jpj * soad2 - aex3 * dum2 * jpu * soad2 - aex1 * dum3 * jop * soad3 + aex1 * dum3 * jpj * soad3 - aex3 * dum3 * jpu * soad3 - aex1*jop*soai + aex1*jpj*soai - aex3*jpu*soai + jpu*jtr*t + jop*t*ta - jpj*t*ta + jop*yda*ydum - jpj*yda*ydum -aex1 * ap1 * jop * log(acultq) + aex1 * ap1 * jpj * log(acultq) - aex3 * ap1 * jpu * log(acultq) - aex1 * ap2 * jop * log(awildq) + aex1*ap2*jpj*log(awildq) - aex1*ainc*jop*log(inc_as) + aex1 * ainc * jpj*log(inc_as) - aex3*ainc*jpu*log(inc_as) + jinv * jpu * log(injapan) + jinc * jpu * log(**100***cjinco/jcpi) + jop * jpu*log(**100***exrate/jcpi) + jop * lq * log(lags) + jop * log(totu) - jpj*log(totu) - jop*pr*log(wpr) + jpj*pr*log(wpr));

5. US Import Quantity From Central America:

Log(qic) = (-((**1**/((-pr) + scp))*((dum1*pr*scd1 + dum2*pr*scd2 + dum3*pr*scd3 + pr*sci - cd1*dum1*scp - cd2*dum2*scp - cd3*dum3*scp - intc*scp - scp*t*tc -   scp*ydc*ydum + cin*pr*Log(caminc) + cp1*pr*Log(ccult) + cp2*pr*Log(cwild) + pr*scp*Log(excame) - lq*scp*Log(lcshr) - scp*Log(totu) + pr*scp*Log(wpr)))));

6. US Import Price From Central America:

Log(cpic) = (-((**1**/(pr - scp))*((cd1*dum1 + cd2*dum2 + cd3*dum3 + intc - dum1*scd1 - dum2*scd2 - dum3*scd3 - sci + t*tc + ydc*ydum - cin*Log(caminc) - cp1*Log(ccult) - cp2*Log(cwild) - scp* Log(excame) + lq*Log(lcshr) + Log(totu) - pr*Log(wpr)))));

7. <u>US Import Price From South America:</u>

$$Log(cpis) = (\mathbf{1}/(-pr + sup))*(ints + dum1*sd1 + dum2*sd2 + dum3*sd3 - dum1*sosd1*sp - dum2*sosd2*sp - dum3*sosd3*sp - sosi*sp - dum1*ssd1 - dum2*ssd2 - dum3*ssd3 - ssi + t*ts + ydum*yds - sep*Log(cpeu\_sa\_arg) + lq*Log(lags) - sp*sp1*Log(scultq) + Log(totu) - pr*Log(wpr));$$

8. <u>US Import Quantity From South America:</u>

$$Log(qis) = (\mathbf{1}/(-pr + sup))*(-dum1*pr*sosd1*sp - dum2*pr*sosd2*sp - dum3*pr*sosd3 * sp - pr*sosi*sp - dum1*pr*ssd1 - dum2*pr*ssd2 - dum3*pr*ssd3 - pr*ssi + ints*sup + dum1*sd1*sup + dum2*sd2*sup + dum3*sd3*sup + sup*t*ts + sup*ydum*yds – pr * sep*Log(cpeu\_sa\_arg) + lq*sup*Log(lags) - pr*sp*sp1*Log(scultq) + sup*Log(totu) - pr*sup*Log(wpr));$$

APPENDIX C

REDUCED FORM FLEXIBILITES ASSUMING NO VARIATION IN QUARTERLY PRODUCTION

Table C.1: The estimated change in the Gulf of Mexico dockside price resulting from a one percent change in selected exogenous variables in the reduced form equations.

Components of Import Prices	**Flexibility**
Asian Cultured Production	-0.29571
Asian Wild Production	-0.12346
Central American Cultured Production	-0.09872
Central American Wild Production	-0.26983
South American Cultured Production	-0.25724
Overall Asian Income	0.99858
Japanese Income	0.11594
Central American Income	0.23321
Weighted Import Price	0.32161
South American Export Price to EU	0.19338
Lagged Import From Asia	-0.11616
Lagged Imports From Central America	0.13710
Lagged Imports From South America	0.14269

VITA

Pawan Poudel was born and raised in Kathmandu, Nepal. After completing his bachelor's degree in agriculture, concentrating on agricultural economics, from Institute of Agriculture and Animal Science, Rampur, Nepal, he worked for a year in Nepal. He began his master's program in agricultural economics, in the Department of Agricultural Economics and Agribusiness, Louisiana State University, Baton Rouge, Louisiana, in spring 2004. After completing his master's degree he would be pursuing his doctoral program.