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The effects of U.S. shrimp imports on the Gulf of Mexico dockside price : a source differentiated mixed demand model

Maryam Tabarestani
Louisiana State University and Agricultural and Mechanical College, mtabar1@tigers.lsu.edu

THE EFFECTS OF U.S. SHRIMP IMPORTS ON THE GULF OF MEXICO DOCKSIDE
PRICE: A SOURCE DIFFERENTIATED MIXED DEMAND MODEL

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Maryam Tabarestani
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ABSTRACT

The volume of U.S. shrimp imports has increased substantially since 1980, largely due to an increase in world shrimp production. More specifically, U.S. shrimp imports have increased from 649 (headless weight) million pounds in 1997 to 1,236 million pounds in 2010, while the price of imports has declined over this same period. United States domestic production of shrimp has remained relatively stable during this period, while the U.S. dockside price declined. These trends suggest that the price-quantity relationship between U.S. domestic landings and the domestic price may be structurally different from the price-quantity relationship between the volume of shrimp imports and the import price. The central thesis of this study is that neither the ordinary demand specification, nor the inverse demand specification, are independently adequate for modeling the U.S. shrimp market. Consequently, a mixed demand model that simultaneously allows for both quantity-dependent and price-dependent specifications is more appropriate for estimating the U.S. demand for shrimp.

The general objective of this study is to develop and estimate a system of demand equations to analyze the U.S. demand for shrimp landed in the Gulf of Mexico. Specifying a valid system of demand equations for the U.S. shrimp market will help researchers and government organizations better understand the determinants of U.S. shrimp demand. To accomplish this objective, a mixed demand system was adopted. A mixed set of demand functions contains both coefficients of a regular demand system and an inverse demand system (Barton, 1989). This study adopts the Brown and Lee parameterization (2006), known as the mixed Rotterdam demand system. The shrimp products were divided into two subgroups: 1) shrimp imports (group a); and 2) Gulf of Mexico shrimp landings (group b). Countries considered in the analysis include China, Ecuador, India, Indonesia, Mexico, Thailand, Vietnam, and a final category includes all other exporting countries. Demand for Gulf shrimp is specified by size of shrimp with three sizes: Large, Medium, and Small. U.S. imports from these countries were modeled in a quantity dependent framework, while demand for domestic shrimp products was modeled in a price dependent framework.

The summary statistics and estimated results for the model parameters indicate that Thailand has the largest share and largest marginal share among all exporting countries and Gulf shrimp landings. As

theoretically expected, all own-price elastisities of regular demand are negative, implying an inverse relation between the quantity of imports from a selected country and its price of imports. Among all countries, China, India, Mexico, and Vietnam have the largest and almost the same own-price elasticities. Thailand's own-price elasticity is smaller than these countries, although it has the largest share of U.S. total expenditures on shrimp products. The Lerner index along with Thailand's largest share in U.S. total expenditures on shrimp reveals that Thailand has some degree of market power relative to China, India, Mexico, and Vietnam in the U.S. shrimp industry.

Cross-price elastisities of regular demand were positive, indicating that the price of a selected country's shrimp products have a direct effect on the quantity of other countries' shrimp exports. The positive cross-price elastisities also indicate that U.S. shrimp imports from different countries are substitutes for each other, as expected. Thailand's export prices have the largest cross-price elastisities.

The price elasticity/flexibility of inverse demand illustrates that no country's export prices have a substantial effect on any size of Gulf landings. The largest effect is associated with about 0.02% on the price of small size Gulf landings for a 1% change in the price of Thailand's exports to the United States.

Vietnam, India, Mexico, China, and Thailand's income elasticities are greater than one. Therefore, one can conclude that a change in U.S. expenditures on shrimp products not only increases the consumption of these countries' shrimp products but that the proportion (share) of these products also goes up in U.S. total expenditure on shrimp. The homogeneity condition results are similar to the conclusion obtained from the Lerner Index, indicating Thailand dominance in the U.S. shrimp market.

Income elasticities for inverse demand represent the Gulf dockside price sensitivities relative to a change in U.S. expenditures on shrimp. Results illustrate that if U.S. expenditure on shrimp products increases by 1%, the Gulf large, medium, and small size shrimp prices will increase 0.12%, 0.15%, and 0.19%, respectively.

CHAPTER 1
INTRODUCTION

Seafood is a major part of U.S. cuisine and the U.S. is ranked third behind China and Japan, in total consumption of fish and shellfish. In 2009, the U.S. total seafood consumption was 4.83 billion pounds with an associated value of $75.5 billion. Shrimp, with a 2009 per-capita consumption of 4.1 pounds, accounted for more than one-quarter of the total 2009 U.S. per capita consumption of seafood (15.8 pounds) (NOAA's Fisheries of the U.S. reports).

Commercial fishing is one of the first industries in the United States as early explorers came to the Gulf coast seeking new lands and "gifts of the sea" (Louisiana Seafood Promotion & Marketing Board). The Gulf of Mexico commercial shrimping industry is large and the contribution of it to local and overall economies can be categorized in several activities associated with processing, packing, wholesale distribution, vessel maintenance, repair, and refueling. Averaging $409 million annually during 2000-09, the dockside value of U.S. Gulf of Mexico (defined as the coastal states extending from the west coast of Florida through Texas) shrimp landings exceeded that of any other species or species groups (NMFS, NOAA, 2010).

Before 1980, the world supply of shrimp consisted primarily of wild product. As a result of technological advances world farm-raised shrimp production has increased, significantly since the early 1980s (Saravanan and Santhanam, 2008).

 The general purpose of this dissertation is to estimate the U.S. demand for shrimp by introducing a new structural demand system that is believe to be, in theory, more theoretically appealing than previous estimation procedures. As a prelude, the remainder of this chapter is devoted to discussing changes in the world shrimp market with special emphasis being given to the U.S. shrimp market. Then the problem statement and objectives of this study are presented.

1.1. World Shrimp Market[1]

The world shrimp supply consists of two products; captured shrimp and cultured shrimp. Growth in the production of these two products over the period of 1970-2011 is considered in figure 1.1. As indicated, captured supply increased from about 1.0 billion pounds (headless weight) during the early 1970s to about 3.0 billion pounds annually during the decade beginning in 2000. Overall, there was as apparent upward trend in the production of wild shrimp through the 1990s and relative stability in the production during the most recent decade.

By comparison, production of cultured shrimp was relatively stable during the 1970s, but thereafter increased rapidly exceeding the one-billion pound mark (headless weight) in 1990. By 2002, production of cultured shrimp had equaled the captured production and thereafter exceeded the production of captured product by an increasing amount. Overall, the production of cultured product increased from 2.39 billion pounds in 2002 to 6.12 billion pounds in 2011, while the production of captured shrimp increased by only 0.63 billion pounds (from 2.28 billion pounds in 2002 to 2.91 billion pounds in 2011).
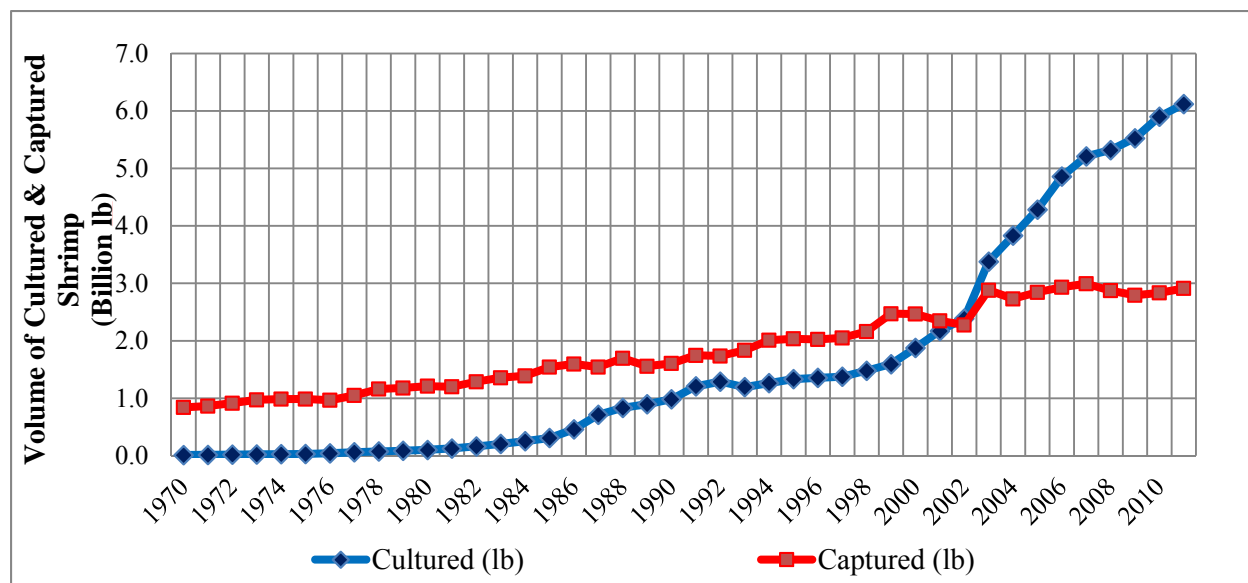
Figure1. 1. World Shrimp Productions by Type, 1970-2011.
Source: http://www.fao.org/fishery/statistics

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[1] All data for this section are converted to headless weight and from tones to pounds.

Primary world shrimp producers, especially cultured shrimp, include Asia, Central America, and South America. In general, production of wild and cultured shrimp in Asia approximated one another throughout the 1990s. Thereafter, cultured production increased rapidly while growth in captured production was much more moderate. Overall, production of cultured shrimp in the Asian region increased from 0.84 billion pounds in 1990 to 5.35 billion pounds in 2011, while production of captured shrimp increased from 0.70 billion pounds to 1.72 billion pounds (figure 1.2).
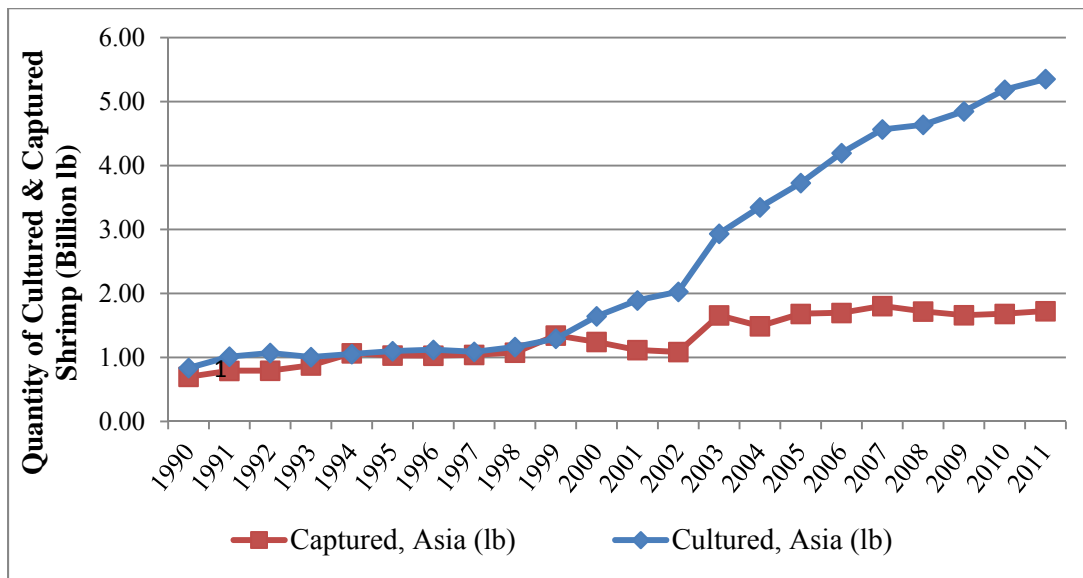
Figure1. 2. Asian Countries Shrimp Productions by Type, 1990-2011.
Source: http://www.fao.org/fishery/statistics

With the exception of a few years in the early 1990s, South American production of cultured shrimp exceeded the production of captured shrimp (figure 1.3). Significant growth in the production of cultured, however, was apparent during the most recent decade. Thereafter, South American production followed a similar pattern to Asian production. Overall, South American production of cultured shrimp increased from 0.13 billion pounds in 2000 to 0.51 billion pounds in 2011 while growth in the production of captured shrimp was much more moderate (from 0.13 billion pounds in 2000 to 0.22 billion pounds in 2011) (figure 1.3).
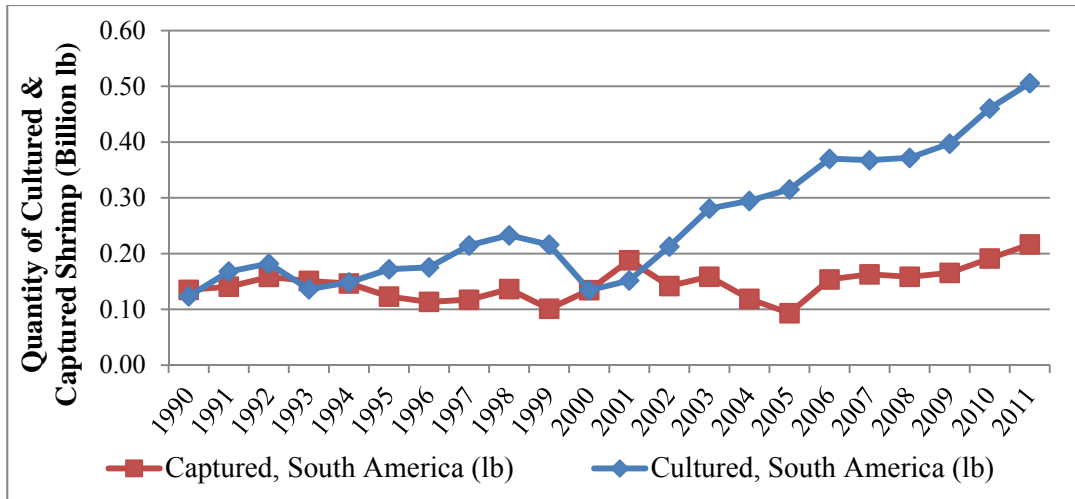
Figure1. 3. South American Countries Shrimp Productions by Type, 1990-2011.
Source: http://www.fao.org/fishery/statistics

Production of captured shrimp in the Central America exceeded the cultured production until 2003 (figure 1.4). Overall, production of captured shrimp in this region exhibited no long-run growth. By comparison, production of cultured shrimp increased from less than 50 million pounds annually prior to the mid-1990s to more than 200 million pounds annually since the mid-2000s.
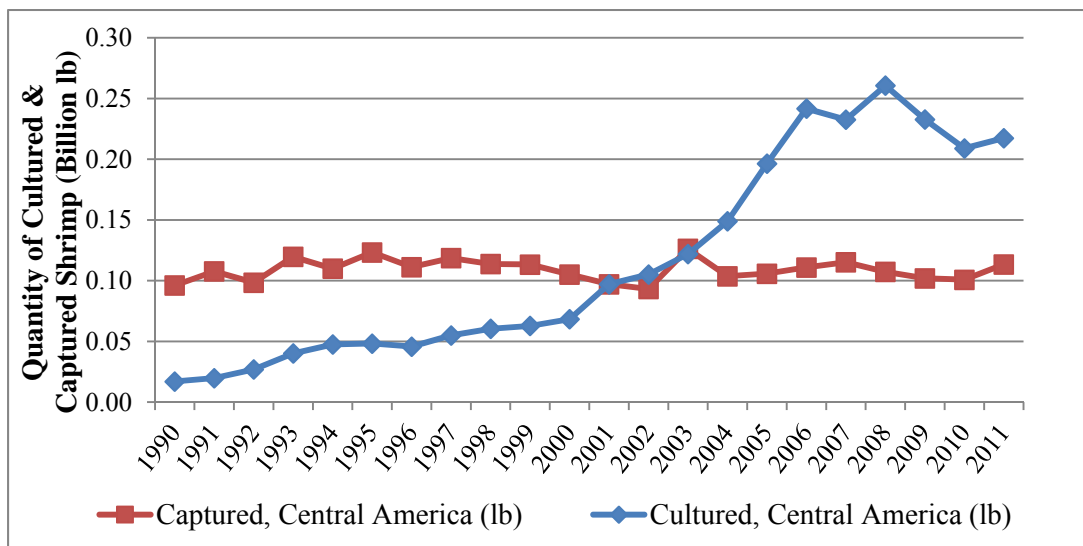
Figure1. 4. Central American Countries Shrimp Productions by Type, 1990-2011.
Source: http://www.fao.org/fishery/statistics

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As indicated by in the information in table 1.1, world shrimp production is dominated by Asia which accounted for 78% of world production in 2009. South America represented as additional 6.8% of world production while Central America accounted for about 4% (table 1.1).

Table 1.1. World Shrimp Production and Share by Region, 1990-2011.

Year	Asia (lb)	Central America (lb)	South America (lb)	Rest of the World (lb)	Total	Asia %Share	Central America %Share	South America %Share	Rest of the World %Share
1990	1.53	0.11	0.26	0.68	2.59	59.2	4.4	10.0	26.4
1991	1.81	0.13	0.31	0.71	2.96	61.1	4.3	10.4	24.2
1992	1.87	0.13	0.34	0.70	3.03	61.6	4.1	11.2	23.0
1993	1.88	0.16	0.29	0.70	3.03	62.2	5.3	9.5	23.1
1994	2.12	0.16	0.29	0.70	3.27	64.7	4.8	9.0	21.4
1995	2.13	0.17	0.29	0.77	3.37	63.2	5.1	8.7	22.9
1996	2.15	0.16	0.29	0.79	3.38	63.5	4.6	8.5	23.3
1997	2.13	0.17	0.33	0.79	3.43	62.1	5.1	9.7	23.1
1998	2.24	0.17	0.37	0.86	3.64	61.5	4.8	10.1	23.5
1999	2.64	0.18	0.32	0.94	4.07	64.9	4.3	7.8	23.0
2000	2.89	0.17	0.27	1.01	4.34	66.5	4.0	6.2	23.3
2001	3.01	0.19	0.34	0.98	4.52	66.5	4.3	7.5	21.6
2002	3.11	0.20	0.35	1.00	4.66	66.8	4.3	7.6	21.4
2003	4.59	0.25	0.44	0.98	6.26	73.4	4.0	7.0	15.6
2004	4.84	0.25	0.41	1.06	6.56	73.7	3.8	6.3	16.1
2005	5.41	0.30	0.41	1.01	7.13	75.9	4.2	5.7	14.1
2006	5.89	0.35	0.52	1.02	7.79	75.6	4.5	6.7	13.1
2007	6.37	0.35	0.53	0.96	8.20	77.6	4.2	6.5	11.7
2008	6.36	0.37	0.53	0.94	8.19	77.6	4.5	6.5	11.5
2009	6.51	0.33	0.56	0.91	8.32	78.3	4.0	6.8	10.9
2010	6.87	0.31	0.65	0.91	8.74	78.6	3.5	7.5	10.4
2011	7.08	0.33	0.72	0.90	9.03	78.4	3.7	8.0	10.0

Source: http://www.fao.org/fishery/statistics

Asia was not only the world's largest shrimp producer but was also the world's largest shrimp exporters; accounting for more than 60% of the world's total exports in 2009. Exports from South America and Central America comprised 11% and 4% of the world's total exports, respectively (figure 1.5). This suggests that relative exports from these three major regions are closely related to production.
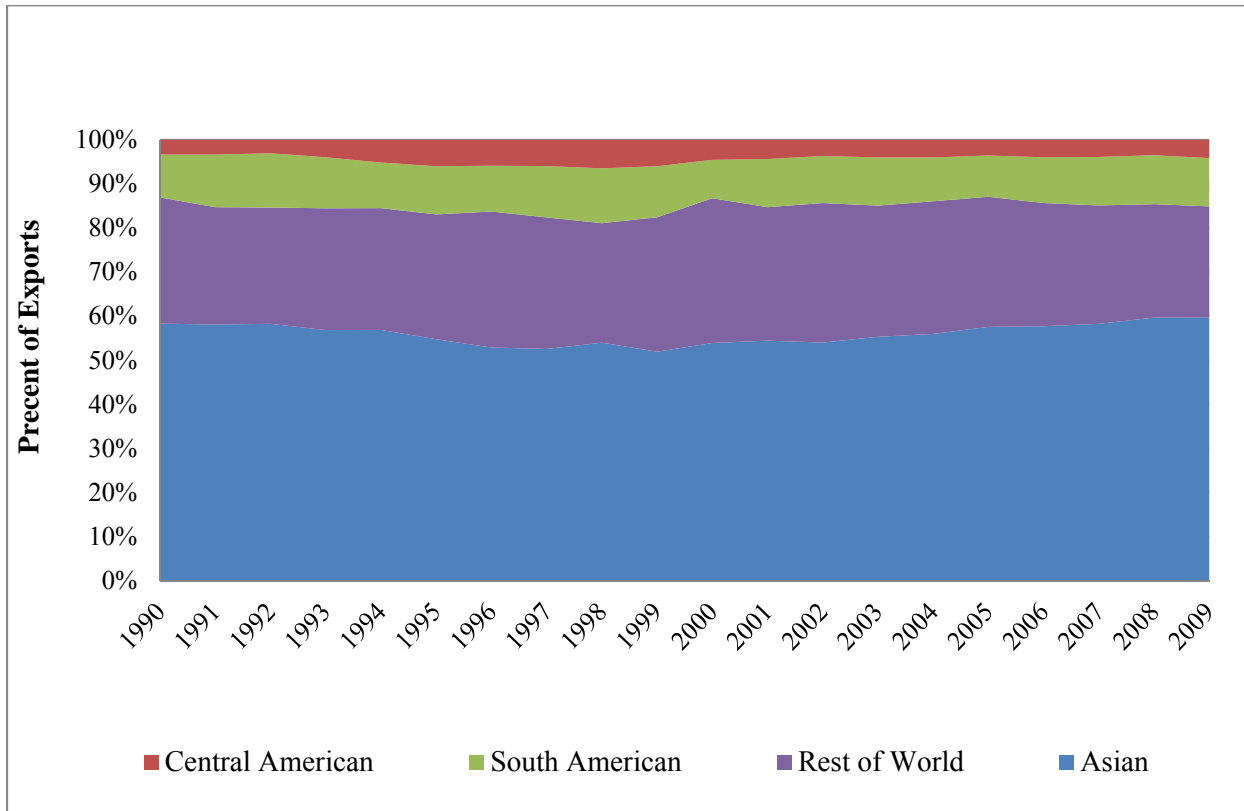
Figure 1.5. World Shrimp Exports Percentage Share by Region, 1990-2009.
Source: http://www.fao.org/fishery/statistics

An increase in the world shrimp productions, especially after 2001, allowed for a rapid increase in world shrimp consumption. The United States, Japan, and European Union represent the primary shrimp importers. In 1990, these three regions imported more than 80% of the world shrimp supply. The total share of these countries/regions fell to 70%, in 2009. Japanese imports declined from 27% to 12% over the period of 1990-2009, while, at the same time, EU and U.S. shares increased from 33% and 21%, respectively, to 36% and 26% (figure 1.6).
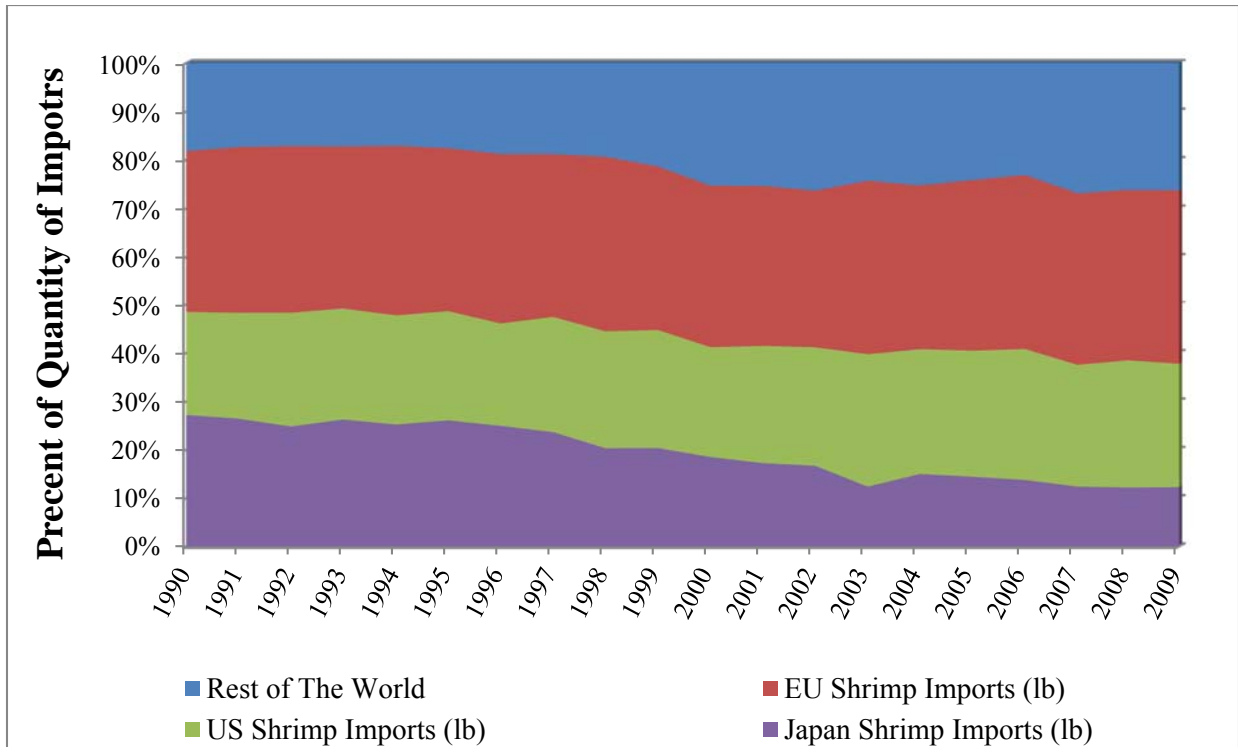
Figure 1.6. World Shrimp Distribution by Country/Region, 1990-2009.
Source: http://www.fao.org/fishery/statistics

1.2. The U.S. Shrimp Market

Annual U.S. shrimp production for the period of 1997-2010, along with imports, is given in table 1.2. As indicated, while imports have been increasing throughout the period of study, there had been no upward trend in domestic production. The Gulf of Mexico accounts for the vast majority of U.S. shrimp production and it is generally believe that effort has historically been large enough to harvest virtually all available shrimp. The long-run stability in domestic production in conjunction with increasing imports implies that the share of U.S. shrimp consumption supplied by domestic production has fallen sharply over time. This is clearly illustrated by information in figure 1.7.

Table 1.2. U.S. Annual Shrimp Landings and Imports, 2000-2010.

Year	Annual Landings		Annual Imports	
	Adjusted[2] Million Pounds	$ Millions	Adjusted[3] Million Pounds	$ Billions
1997	117.90	437.82	648.86	2.96
1998	150.80	461.21	696.09	3.11
1999	143.81	463.98	732.26	3.14
2000	173.48	640.40	762.11	3.76
2001	151.42	480.09	883.89	3.63
2002	138.50	370.56	947.67	3.43
2003	153.69	346.85	1,113.03	3.76
2004	154.86	353.53	1,142.83	3.69
2005	131.66	348.15	1,173.21	3.67
2006	178.47	385.56	1,307.22	4.14
2007	138.34	354.32	1,231.79	3.91
2008	116.01	354.54	1,248.89	4.11
2009	142.08	292.85	1,217.41	3.78
2010	108.66	328.21	1,236.39	4.29

Source: http://www.st.nmfs.noaa.gov/
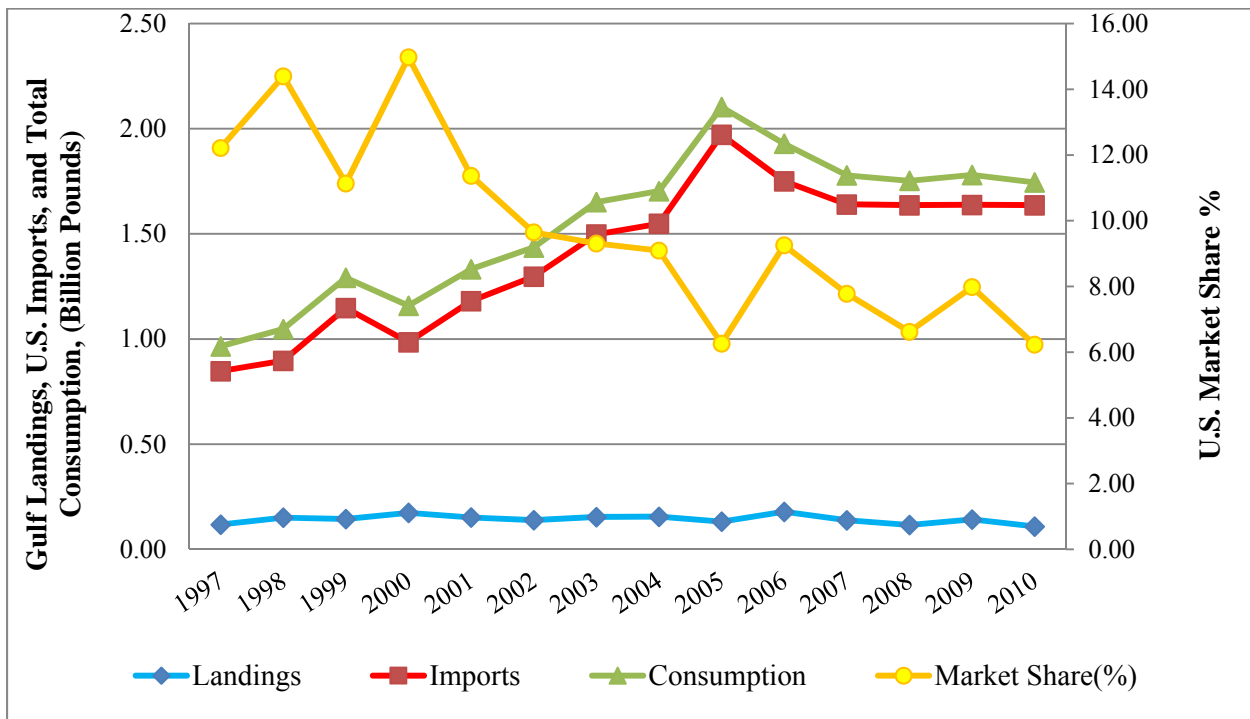
Figure 1.7. The U.S. Shrimp Landings, Imports, Consumption, and Market Share, 1997-2010.
Source: http://www.st.nmfs.noaa.gov/

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[2] Shrimp landings are converted to headless weight.
[3] Imports are converted to headless weight and from kilograms to pounds.

1.2.1. The U.S. Domestic Shrimp Market

The Gulf of Mexico is the largest shrimp producing region in the United States with production from the region generally accounting for more than 70% of the nation's total. White, pink, and brown shrimp are the major species harvested in the Gulf of Mexico (NOAA, 2010). In addition to the types of products, National Marine Fisheries Service reports the Gulf of Mexico shrimp landings in eight size categories (headless weight).

Though exhibiting significant variation annual Gulf of Mexico landings have exhibited no increasing trend over the past twenty years (figure 1.8). Overall, annual production has varied from a low of 123 million pounds in 1980 to maximum of 135 million pounds in 2011.
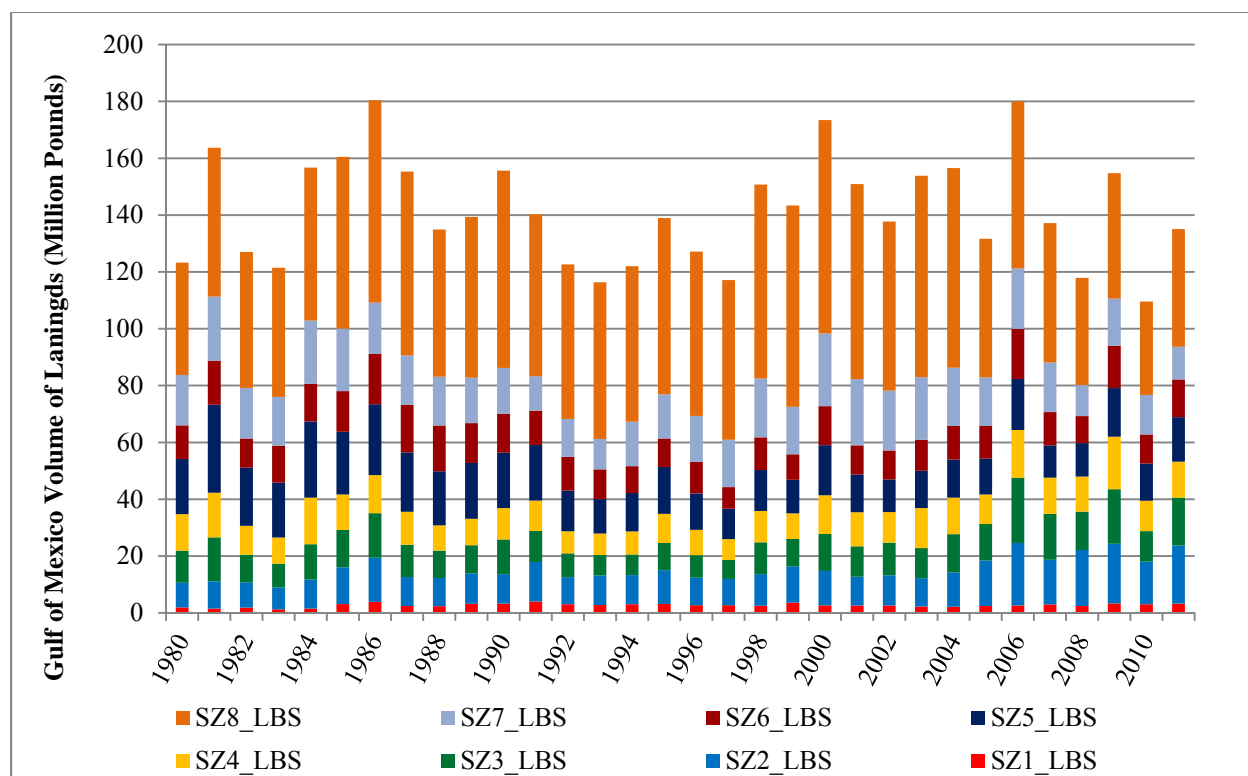
Figure 1.8. The Gulf of Mexico Shrimp Landings by Size, 1980-2011.
Source: http://www.st.nmfs.noaa.gov

Despite long-run stability of Gulf of Mexico production, the dockside prices are declining over time. Poudel and Keithly (2008) suggest that the U.S. imports are the main reason for the decline in the Gulf dockside prices particularly since 2001.

On the other hand, U.S. shrimpers have been experiencing an increase in diesel fuel prices since 1997 (EIA, 2011). As estimated by Ward, Ozuna, and Griffin (1995), fuel costs comprise almost 25% of the total cost of commercial shrimp fishing in the Gulf of Mexico. A reduction in revenue due to a decline in the Gulf dockside price along with an increase in operating costs due to increase in diesel price has resulted in a classic cost/price squeeze. This condition resulted shrimpers exiting industry. In 1981, for example, the annual number of unique shrimpers' vessels in the Vessel Operating Units File (VOUF) exceeded 6200. It had fallen to less than 4200 by 2002 (Nance, 2004). During the same period, the annual total number of shrimp trips taken in Gulf of Mexico offshore waters fell from more than 85,000 to less than 40,000[4] (Nance, 2004).

1.2.2. The U.S. Shrimp Imports

The U.S. imported more than a quarter of the world total shrimp supplies in 2011 and trails only European Union in terms of shrimp imports. The U.S. imports several shrimp products that have been segmented into 19 categories in National Marine Fisheries Service/Science and Technology website. For simplicity, these categories are rearranged into five groups in figure 1.9, which shows the U.S. shrimp imports for the period of 1991- 2011.

During the 1991-2011 period the volume of all types of imported shrimp, except shell-on small size, have increased. However, relative shares have changed. Peeled frozen and fresh shrimp and miscellaneous shrimp shares, for example increased from 34% and 7% in 1991, respectively, to 38% and 21% in 2011, by comparison, the shares of the other three products (Shell-on large, Shell-on medium, and Shell-on small) declined. Peeled frozen and fresh have the largest share among all types of shrimp imports

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[4] The length of trips can range from 1 to 60 days long.

in 2011. At the same time, shell-on large and medium have the largest share after peeled shrimp and their

shares are almost the same (19% and 20%, respectively).
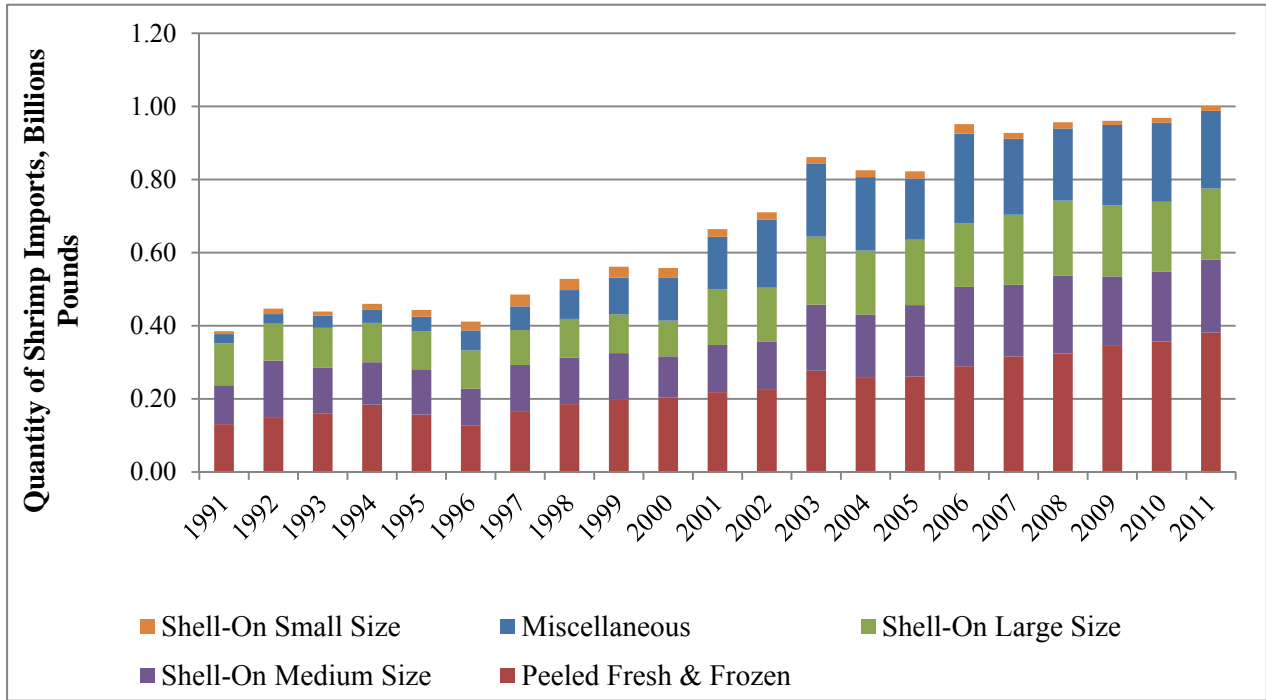
Figure 1.9. The U.S. Shrimp Imports by Product Type, 1991-2011.
Miscellaneous = Breaded Frozen + Products Prepared for Dinners+ some other small volumes of imports.
Shell-on Large= Shell-on Frozen < 15+ Shell-on F. 15/20+ Shell-on F. 21/25+ Shell-on F. 26/30.
Shell-on Medium= Shell-on F. 31/40+ Shell-on F. 41/50+ Shell-on F. 51/60+ Shell-on F. 60/70.
Shell-on Small= Shell-on Frozen > 70.
Source: http://www.st.nmfs.noaa.gov.

The U. S. imports these products from more 50 countries around the world. These countries are

including Asian, South America, and Central America countries. As figure 1.10 illustrates, Asian countries

are the major shrimp exporters to the United States, having more than 75% of the share in 2011. South and

Central America's countries share 17% and 6% of the U.S. shrimp imports in 2011, respectively. All other

countries including European and African countries only share 1% of the U.S. total imports.
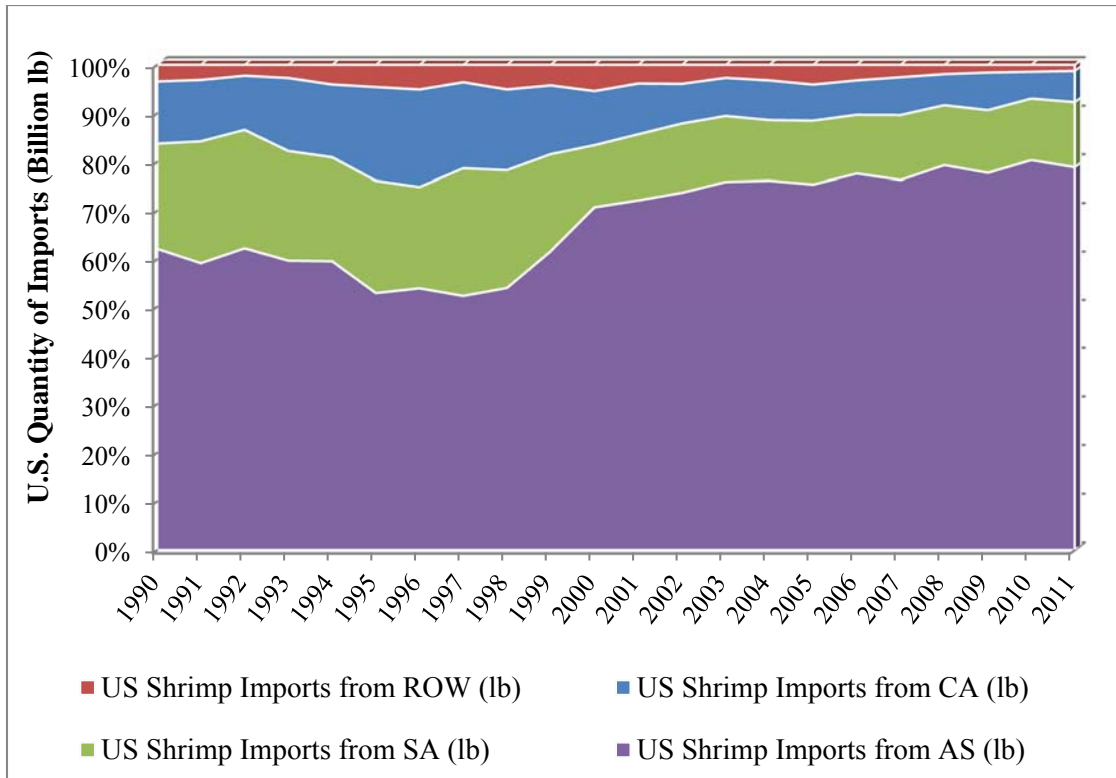
Figure 1.10. The U.S. Shrimp Imports by Source Origin, 1991-2011.
 Source: http://www.st.nmfs.noaa.gov

With growth in the world shrimp supply exceeding that of growth in world demand, the world shrimp price has fallen significantly since the early 1990s (figure 1.11). Given that imports represent such a large share of total U.S. supply (i.e. imports plus domestic production), one might expect that the domestic price follows that of the import price. This, as indicated in figure 1.11, is clearly the case. Overall, the U.S. domestic shrimp price mirrors the world shrimp price (figure1.11) suggesting that imports, at least in part, heavily influence the domestic shrimp price (Keithly and Poudel, 2008; Asche et. al., 2011).
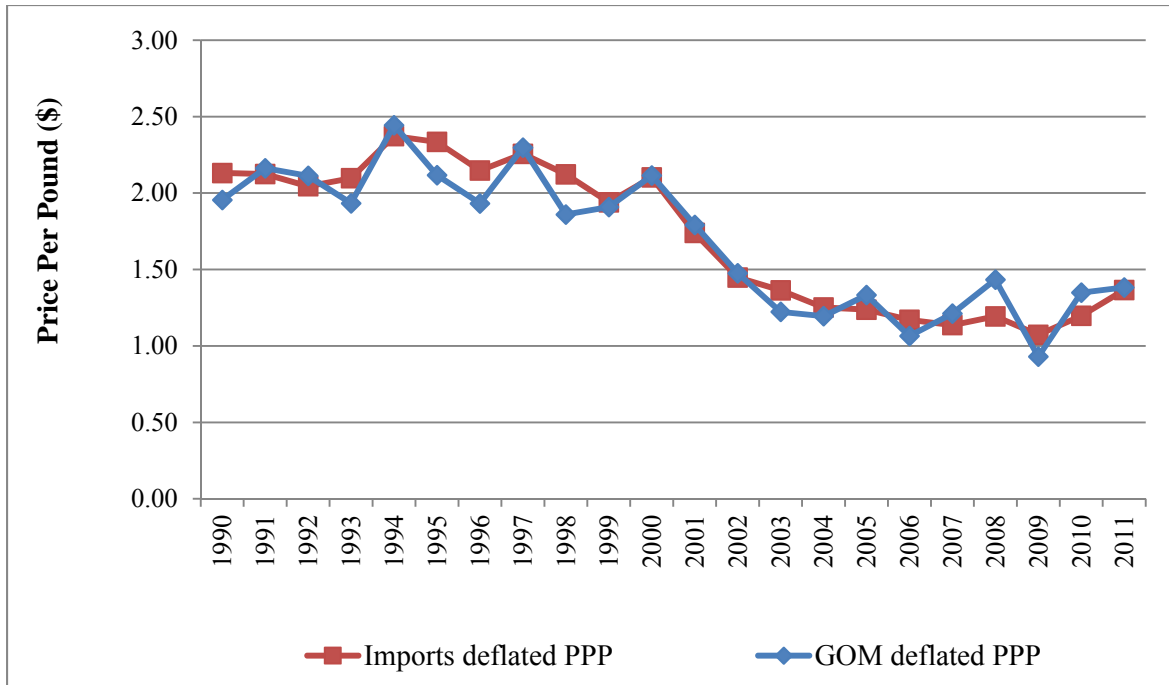
Figure 1.11. Shrimp Imports Price per Pound and Gulf of Mexico Dockside Price per Pound, 1990-2011.
Source: http://www.st.nmfs.noaa.gov

Comparing the Gulf of Mexico shrimp landings and the U.S. shrimp imports illustrates how small Gulf landings are relative to imports; the imported shrimp comprises a large share of the U.S. shrimp supply (more than 80%).

1.3. Problem Statement

In a brief, a significant increase in world shrimp production particularly after 2000 resulted in a rapid increase in U.S. imports. As indicated, Gulf shrimp producers' revenue decreased as a result of decline in dockside prices. On the other hand, increase in fuel prices raised the shrimp producers' operation costs. These two factors together forced many Gulf shrimpers to leave the market and decreased the number of Louisiana's commercial fishing vessels and fishing boats from 15,800 in 1994 to 10,958 in 2002 (NOAA, NMFS, 1994 and 2002). During the same period, the annual total number of shrimp trips taken in Gulf of Mexico offshore waters fell from more than 85,000 to less than 40,000[5] (Nance, 2004). These facts imply

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[5] The length of trips can range from 1 to 60 days long.

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that the price variability can have disadvantageous influence on domestic producers and even the industry. Therefore, the price determination mechanism in U.S. shrimp market is an important subject. The shrimp market needs more investigation and studies to provide facts and information that can address this subject and help policy makers to find proper solutions for improving the shrimp producers' situation. In spite of the importance of the shrimp industry in the Southern states and its share in the U.S. fishery industry, there have been only a few studies addressing this subject. To accomplish this goal, this study attempts to apply a new structural demand system model, known as the mixed Demand model, to analyze and quantify the determinants of U.S. shrimp demand and the factors which are affecting domestic prices (Gulf of Mexico dockside prices). In this analysis, the U.S. demand for imported shrimp and domestic shrimp (Gulf of Mexico landings) differentiated by exporting country and size classification, respectively.

1.4. Objectives

The general objective of this study is to develop and estimate a system of demand equations to analyze the U.S. demand for shrimp. Specifying a valid system of demand equations for the U.S. shrimp market will help researchers and government organizations better understand the determinants of U.S. shrimp demand. Because of the important role of shrimp products in the U.S. seafood industry, finding the key factors that influence demand is an important issue. Specifically, this study proposes the following objectives:

1) To specify a theoretical model that accurately depicts the U.S. demand for shrimp and which differentiates imported shrimp from domestic production in the analysis;

2) To empirically estimate the model developed under objective 1;

3) To estimate price and income elasticities of shrimp imports, by source and determine whether source is an important factor in determining domestic price;

4) To empirically estimate the quantity and scale flexibilities of Gulf shrimp demand.

The remainder of this study is organized as follows: in Chapter 2, the literature of shrimp market studies and mixed demand model will be reviewed. In Chapter 3, the mixed demand system and especially

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mixed Rotterdam demand model will be introduced. Then the mixed demand system for this study will be parameterized. Chapter 4 will include the mixed Rotterdam demand examination for the U.S. shrimp market. The interpretation of estimated results will be also provided in this chapter. Finally, in Chapter 5, the conclusion of application of mixed demand in the U.S. shrimp market and its potential contribution to the policy implications will be presented.

CHAPTER 2
LITERATURE REVIEW

2.1. Shrimp Market Studies

The demand side of the shrimp market has been the subject of several studies. Some of these studies have applied traditional microeconomic theory (Cleary, 1969; Haas, et Al., 2001) while others have used a stated preference methodology based on Conjoint Analysis. These latter analyses have examined purchasing behavior in relation to preferences and attitudes (Rhodes, Greene, and Sanifer, 1990; Wirth and Davis, 2002; Wirth, Dugger, and Creswell, 2004; Barbier, 2004).

Inspired by previous studies on agricultural goods, Yanagida and Tyson (1984) developed two dynamic equations to investigate the effects of habit formation and inventory adjustment on shrimp consumption. Their model uses monthly shrimp consumption data and its one month lag as dependent and independent variables, respectively. Other variables in the analysis include deflated retail raw headless shrimp price (36-42 count), deflated per capita personal income, and a dummy variable to capture seasonality effects in both equations. The researchers also include a stock variable in the second equation to capture the effect of inventory adjustments on shrimp consumption. Application of the lagged consumption variable in the model is used to quantify the influence of habit formation[6] on current consumption. With the exception of per capita income and stocks characteristics, all estimated coefficients had theoretically consistent signs and were statistically significant. The analysis indicated that monthly shrimp consumption is inelastic, with respect to the monthly price in the short-run. The consumer habit has a significant effect on his/her consumption. As the per capita income coefficient in the shrimp demand equation has not only unexpected sign (negative sign) but is also statistically insignificant, the authors conclude that consumers prefer to consume shrimp in restaurants instead of household.

Other researchers have developed a system of simultaneous equations model which includes both demand and supply functions (Gillespie, et al. 1969; Doll, 1972; Thompson and Roberts, 1982; Adam, et.

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[6] Habit formation is one type of "time non-separable" preference function that refers to the individual's own past consumption levels.

al. 1987; Keithly, et. al. 1993). Doll (1972) formulates a system of five simultaneous equations to build a structural model of the U.S. shrimp market and evaluate the impact of imports on ex-vessel prices. In this study, Doll composes ex-vessel prices, U.S. shrimp consumption and ending stocks as jointly determined variables and shrimp supplies and consumer income as predetermined/exogenous variables. He considers the volume of imports and the beginning stocks as alternative supply sources for the landings in the consumption equation. After running the system by applying annual data, he concludes that domestic (ex-vessel) prices are significantly influenced by imports with increases in the later dampening the domestic price. In his study, Doll calculated the short-run and long-run multipliers: impact, cumulative, and equilibrium. Both the domestic landings and imports have a significant effect on the ex-vessel prices; however the effect of shrimp landings on domestic prices was approximately twice that of the effect of imports.

Following the Doll study, Thompson and Roberts (1982) attempted to forecast ex-vessel shrimp prices for the Northern Gulf of Mexico. Their model included seven simultaneous equations and differs from the model proposed by Doll in a number of important features. Specifically, whereas Doll employed annual data in his analysis, Thompson and Roberts apply monthly data. Furthermore, Thompson and Roberts regard the quantity of shrimp landings and import quantities, as well as fishing effort, as jointly determined variables. As such, Thompson and Roberts treat imports as an endogenous variable, while Doll treats imports exogenously in his system. Analysis by Thompsonand Roberts (1982) indicates that landings, imports, and stocks have a significant effect on price prediction. They conclude that substitute and complementary goods are also important to forecasting the northern Gulf of Mexico dockside shrimp price. It should be noted that both of these models were conducted prior to the large increase in imports brought about, primarily, via increasingly.

Adams, et. al. (1987) adopt a causal relationship model to assess the dynamic nature of price leadership between adjacent market levels and to determine the factors influencing the price in each market level. They use monthly and quarterly data for 31-40 size and 21-25 size classes of raw-headless shrimp. They consider four vertical market levels for shrimp products: 1) retailer; 2) wholesaler-processor; 3) first

handler; and 4) producers. Prices at each level are a function of quantity demanded at that level, costs of marketing inputs (for the last three levels) connected to present the product to consumers, retailers, and wholesaler-producers, respectively, a set of consumer demand shifters for the first level (retailer), and a set of prices involving subsets of current or lagged dependent and pre-determined prices appropriate for a specific market. In this system of four equations, causal variables include imports, landings, beginning inventories, income, a cost index of marketing inputs, and prices of competing meat products. For the causal relations investigation, Adams, et. al. (1987) apply data for the period of 1968 to1981. However, due to the unavailability of data for quantity of shrimp, costs, and income, the researchers use data from 1972 to 1981 for the analysis of price models. Some of their key findings of the causal analysis reveal that none of the mentioned market levels have an effective market power to allocate more market share to itself or to transfer its costs to other levels; therefore, there is no monopolistic pricing in the shrimp industry. The estimated price relationships demonstrate that imports and government policies can affect all market levels. Since the impact is almost equivalent at the wholesale and ex-vessel levels, but substantially greater at the retail level, the price of small size shrimp is able to adjust faster than large size shrimp prices.

Diop, et. al. (1999) examine the role of shrimp imports on the U.S. southeastern (i.e., coastal states from North Carolina through Texas) shrimp processing industry. The model contains three demand equations for three levels of the shrimp industry: retail, wholesale, and ex-vessel. In contrast to the Adams, et. al. (1987), Diop, et. al. (1999) consider four forms of shrimp products (rather than two-size shrimp) in their investigation: headless-shell-on, peeled, breaded, and "other" shrimp. They adopt a three-stage least square technique and estimate the structural and reduced form equations for the observations from 1973 to 1996. The results of their study reveal that retail demand functions are price inelastic, but that wholesale demand functions are price elastic except for breaded shrimp.

Similar to the findings by Adams, et. al. (1987), results by Dio, et. al. (1999) indicate that a change in policy measures will impact all market levels. For example, an increased trade restriction reduces the available supplies which, in turn, cause prices to increase and then the wholesale processor margins will also goes up. Their analysis, however, suggests that the influence of imported shrimp on the wholesale level

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exceeds that at either the retail or ex-vessel level. Analysis by Adams, et. al. (1987), by comparison, suggests that the effect of a policy, such as increased trade restriction, on prices is greater at the retail level than at wholesale level or ex-vessel level. In addition to the simultaneous equations specification, researchers have employed Inverse Demand System (IDS) or Inverse Almost Ideal Demand System (IAIDS) in identifying the determinants of shrimp demand and price and income flexibilities. Employment of IDS and IADS are based on the premise of ad highly inelastic supply function for shrimp. for example, arguing that the annual domestic supply of shrimp is fixed, Houston and Nieto (1988) specified an inverse demand function (a price-dependent function) to study the factors affecting the distribution of fresh shrimp in four major U.S. producing regions including Gulf of Mexico, Florida, North Carolina, and South Atlantic. In an equilibrium condition the annual domestic regional shrimp prices have been expressed as a function of quantity of landings (own region and outside region), the quantity of net imports, the quantity of the carry-over stocks, and total disposable income. Formulating a system of equations for each region comprised of size, and species. The authors apply a seemingly unrelated regressions (SUR) model. Their model includes four regions: Gulf of Mexico, Florida, North Carolina, and South Atlantic; three species: brown, pink, and white; and three different sizes: small, medium, and large. They estimate price flexibilities and the results indicate that the import impacts, the landings' variation in the species and the size composition impacts, and the real disposable personal income impacts on deflated regional prices differ in every region.

The most recent shrimp demand analysis is that conducted by Jones, et al. (2008). In this study, unlike previous investigations, a differential approach is used for analysis. The researchers apply Netherlands Central Bureau Statistic (CBS) specification to estimate U.S. demand for domestic and imported shrimp for the period of 1995 to 2005. The researchers consider eight demand equations for the shrimp imports and domestic product. Although, shrimp imports from six countries – Mexico, Ecuador, India, Thailand, Vietnam, and China – are considered in the analysis as well as an additional category for remaining imports from the rest of the world. These seven equations, as well as U.S. domestic production, represent the eight equations in the complete demand system. Using nonlinear maximum likelihood

approximation, the researchers estimate sixteen versions of the model based on an arrangement of the four dynamic and the four monthly dummy/intercept hypotheses. The results demonstrate that shrimp demand follows a seasonal pattern, that is, it may change from month to month, while its annual pattern is stable. The conditional own-price elasticity estimates for all countries were less than -1 in magnitude and were statistically significant. Accordingly, Jones, et. al. (2008) conclude that the demand for imported shrimp is inelastic. The estimated cross-price ealsticities associated with imports from the various countries were, with some exceptions, negative and statistically significant implying that there are complementary relations among imported shrimp products from the various countries. The researchers do not attempt to explain whether this finding conforms to economic theory.

In chapter 1, it has been explained, in detail, that the quantity of Gulf landings has been stable for more than three decades; however, the price of shrimp landings has had a downward trend. Muhammad and Hanson (2009) explicitly explain why an inverse demand is the best specification for almost all seafood demand analysis. The perishable nature of seafood, especially fresh seafood, is associated with an inelastic short-run supply function. In this instance, Gulf of Mexico harvested shrimp (as kind of seafood) quantities are dockside landings which are comparatively fixed in short-run. It is the reason that almost all shrimp demand studies are applied inverse demand (price dependent) functions to analyze this market. It means, in this market, at a given quantity the price of landings should be adjusted to clear the market.

On the other hand, as illustrated in chapter 1, there are several potential sources for the exporters to send their shrimp productions to a country or a region in which prices are higher, relative to other countries/regions. It is the reason that the U.S. imported shrimp demand is assumed to specify as quantity dependent function. It means to clear this market the quantity of demand should be adjusted at a given price. Therefore, one can easily conclude that there is not a similar relationship between the quantity and price of U.S. domestically harvested and imported shrimp. This study contributes to the shrimp demand literature by applying a new model for the U.S. shrimp market, the mixed Rotterdam demand system. In addition, the mixed model which is used in this study provides a theoretical framework to deliberately aggregate

consumption behavior (Chavas, 1984). Consequently, the remainder of this chapter is allocated to a review of studies using the mixed demand specification for other agricultural goods other than shrimp.

2.2. Mixed Demand Studies

Some agricultural economics researchers believe for many agricultural goods being processed and distributed with diverse shapes and preparations, one should not consider only one specified demand function (Barten, 1992; Chavas, 1984; Moschini and Vissa, 1993; Moschini and Rissi, 2006 and 2007; Brown and Lee, 2006). That is, the fresh products which are quickly perishable and have biological, seasonal variation in the supply do not have the same demand function as frozen one which can last for a longer period of time (Samuelson, 1965; Barten, 1992; Brown, Lee, and Gao, 1993; Brown and Lee, 2006; Paulus, 1975; Chavas, 1984). Regular demand functions are suitable for the explanation of price and quantity relationship of that sub-group of goods which can be stored for the time in which the demand is high enough. Likewise, for the description of a quickly perishable sub-group of commodities inverse demand equations are more appropriate (Barten and Bettendorf, 1989). A mixed demand function is the one that seems to appeal to the types of agricultural commodities that have various combinations with different reactions in the market or industry. The mixed system concept in consumer behavioral theory was first introduced by Samuelson (1965). After Samuelson, Chavas (1984) and Cunha-e-Sa, and Ducla-Soares (1999) expand its theoretical aspects. While this concept has been used effectively as the object of market structure studies of several agricultural commodities such as meat/livestock products (Heien, 1977; Moschini and Vissa, 1993; McLaren and Gary Wong, 2009), fruits (Brown and Lee, 2006), and vegetables (Moschini and Rizzi, 2007; Barten, 1992), Cunha-e-Sa et al. (2004) apply this specification to develop an approach to test the consistency situations between travel cost and contingent valuation data. Gao, Wailes, and Cramer (1996) illustrate a mixed Rotterdam demand system in an empirical analysis of consumption of rationed and non-rationed food in China. These two latter studies have adopted the mixed demand concept but have used them in different meaning. All of these research papers have shown the primary importance of specifying a consistent method with the market structure to empirical study in demand analysis. In support of Samoelson's mixed demand theory, Chavas (1984) argues that an ordinary demand

function, which expresses the quantity of demand as a function of prices and consumer income, is not the only and inevitably the best way of the specification of demand relationships. According to the duality concept, an inverse demand system which illustrates the relationship between prices as dependent variable and quantity demanded as pre-determined variable is also, in some cases, an appropriate model for demand analysis. An alternative approach that is between the two other polar cases is the mixed demand system of equations. This method, which regards demand relationships as a function of mixed groups of quantities and prices, provides a more convenient way than estimating a simultaneous system of demand and supply equations (Moschini and Vissa, 1993). Based on consumer preference theory, a regular demand is obtained through the utility maximization problem. To attain an inverse demand function, one can apply a cost minimization problem or use Roy's identity and Shephard's lemma (based on duality theory). The mixed demand system is also accomplished by maximizing consumers' utilities. The difference between this method and the two others is the presentation of direct and indirect utility functions. In a regular demand, a direct utility function is maximized while in an inverse demand, an indirect utility plays a role (Heien, 1977). In a mixed demand system, both of these functions together have an essential application (Samuelson, 1965). A set of mixed demand equations contains the coefficients of a regular demand system and of an inverse demand system together (Barton, 1992).

One of the earliest applications of mixed demand systems relates to Barten's study of vegetables in 1992. Barten argues that canned vegetables are common substitutes for fresh vegetables. In some seasons, because of biological production lags, fresh vegetables are rare in the market. During this time, the preserved vegetables will relatively fill the gap caused by the seasonal variation in the supply of fresh vegetables in the market. Therefore, Barten believes vegetables can be divided into two general groups: fresh and canned. By taking into account a different market adjustment for these two groups, Barten designs the mixed Rotterdam demand parameterization for a set of eight types of vegetables in which five types belong to fresh vegetables and three types are associated with canned or other preserved vegetables categories. However, to estimate the model's parameters, he employs a regular Rotterdam system of equations by considering the endogenous nature of fresh vegetable prices. To eliminate the seasonality

effect in the residuals, Barten adds seasonal dummy variables to his model. The Maximum Likelihood Estimation approach is applied to estimate the model's parameters over the first quarter of 1975 to last quarter of 1984. Barten's estimated elasticities do not support his intuitive expectations that canned and other preserved vegetables are mutual substitutions for fresh vegetables, while they are statistically significant. He mentions that to find an answer to this problem, the Allais characterization of substitution and interaction needs to be used. To compare the difference between considering an endogenous nature for some prices rather than an exogenous one, he estimates a regular demand system where all prices are exogenous and all quantities are endogenous. The estimated results demonstrate that the absolute value of the price effects increase in the equilibrium relations when the endogenous nature of some prices is taken into account.

There are also some other studies that are applied mixed demand specification for some other reasons rather than Barten's description of the nature of agricultural foods. These studies include Moschini and Vissa (1993), Cunha-e-Sa et al. (2004), and Gao, Wailes, and Cramer (1996).

Moschini and his colleagues, Vissa and Rissi have focused on several specifications of mixed demand systems, such as Rotterdam, Stone-Geary, and Normalized Quadratic models. Moschini and Vissa estimate a set of mixed Rotterdam demand relations for the Canadian meat industry, including beef, pork, and chicken, using quarterly data on consumption and prices for the first quarter of 1980 to the first quarter of 1990. Moschini and Vissa explain why a mixed demand is an appropriate specification for the Canadian meat market. Canada is importing some of their beef and pork products from the United States. They believe that the Canadian beef and pork market are following a free trade market. In this instance, it is rational to take into account the prices of these two productions as pre-determined, because the beef and pork international trade market equilibrium assigns the prices. So, Canadian importers are price takers. In the chicken market, however, there is a different relationship between the quantities of supply and prices. Chicken producers have constituted their own organizations and have gained enough power to control the amount of supply in the market. Therefore, the Canadian chicken market will be cleared with the adjustment of price rather than quantity. Accordingly, Moschini and Vissa organize a mixed system of three demand

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equations; two regular demands for beef and pork products and one inverse demand for chicken products. By using the mixed Rotterdam model, Moschini and Vissa estimate weighted compensated mixed elasticities for beef, pork, and chicken. Consuming these estimated parameters and elaborating on Slutsky relations, they calculate the Marshallian mixed ealsticities and direct Marshallian and direct compensated elasticities. Their results demonstrate that estimated mixed elasticities and estimated direct elasticities are the same for beef and pork, but the estimated own-price elasticity for chicken from the mixed demand is greater than the one which is estimated from the regular demand.

Most of the literature about the mixed demand is devoted to mixed Rotterdam demand specification. Moschini and Rissi are the ones who have also worked on other specifications such as Stone-Geary and Normalized Quadratic models. In 2006, Moschini and Rissi introduce the mixed Stone-Geary demand system and apply this specification for the Italian vegetables market. A more noticeable issue in this study is the comparison of the ordinary Stone-Geary demand system and mixed Stone-Geary demand system by implementing the Monte Carlo method, before deployment of the model for Italian vegetables. The derived results demonstrate that none of their estimated true models present bias. However, when they project the mixed model with the Monte Carlo true data generating process as the regular model (or vice versa) an essential bias appears. In this regard, they conclude that an estimation of an ordinary model when the true model is the mixed specification causes an "error-in-variable" problem that induces inconsistent estimators. Their model is fit for monthly data over the period of January 1997 to April 2004. Their variables include the total expenditure, quantity, and price per unit cost measure in euro/kg. They also formulate the normalized prices rather than the nominal one. Similar to Barten's investigation, they divide the vegetables into two major groups: fresh vegetables and frozen and canned vegetables. The regular demand equations are made up of two frozen and canned vegetables, while inverse demand equations are made up of seven fresh vegetables. Therefore, their system is comprised of nine equations. To eliminate the seasonality effects and serial correlation in the estimated residuals, they comprise quarterly dummy variables and first-order serial correlation AR(1) equations, respectively. To estimate the system's parameters, they use the Maximum Likelihood method adopting the TSP software package. According to the adjusted R^2 and Durbin

Watson (DW), all nine individual equations are a fairly good fit. All the estimated coefficients, except one, are statistically significant at a 1% level. The parameter estimates for seasonality effects demonstrate that the Italian vegetables market follows a seasonal pattern. Similar to the Moschini and Vissa (1993) study, they also calculate the ordinary demand elasticities: price and income elasticities. The model's own-price elasticities are all negative which indicates that the Stone-Geary regularity conditions are satisfied. The estimated expenditure elasticities illustrate that the demand for fresh vegetables is less elastic than frozen and canned products. They also approve of Moschini and Vissa's (1993) consideration that mixed demand estimations illustrate more elastic demand relations than regular demand estimations. Moschini and Rissi have also comprised another specification of mixed demand in 2007, Normalized Quadratic mixed demand system. They apply the same Italian dataset as their previous study regarding to the mixed Stone-Geary demand system in 2006. The only difference in this study is the model specification, which is the mixed Normalized Quadratic demand system. They maintain a TSP software package to estimate model parameters. The estimated R^2 and Durbin Watson illustrate that the model is fit well and the first-order autocorrelation equation AR(1) could carry out the system's serial correlation. They also calculate Marshallian mixed elasticities, including own-price and own-quantity ealsticities, and expenditure elasticities at the sample mean of their corresponding variables. The own-quantity elasticities estimates for the price equations are one and less than one in absolute value which indicate that ordinary demand for vegetables is inelastic. The own-price elasticities estimates for the quantity equations state an almost inelastic demand for both frozen and canned vegetables.

Moschini and Rissi project a restricted cost function, rather than a utility function, on a Stone-Geary specification for the first study and Normalized Quadratic for the second study to generate empirical mixed demand models. In both specifications of mixed demand systems, they analyze the same market at the same period of time. In this instance, the issue that one may expect to be answered regarding specification, Stone-Geary and/or Normalized Quadratic, is which model is more appropriate for this kind of market/data. This is the subject in question.

In an extensive study, Wong and Park (2007), provide three applicable mixed demand specifications, Normalized Quadratic Model (NQM), Quadratic Almost Ideal Mixed Demand System (QAIMDS), and Nested Constant Elasticity of Substitution (CES) and adopt them for the Japanese meat and fish consumption. These systems have been derived based on the Hicksian conditional cost function, as Moschini and Rissi applied for Stone-Geary and Normalized Quadratic mixed demand system. The obtained systems are applied to the demand for meat and fish markets using monthly data for six Japanese aggregated categories of fish and meat consumption. Among these six categories, three products are associated with the ordinary demand equations (group A) and three other are related to the inverse demand equations (group B). Via GAUSS software package, they adopt the full information maximum likelihood algorithm to estimate the parameters of their models. To eliminate the serial correlation they imposed the first order autocorrelation strategy in the models. Their results show that all three models are well fit. The likelihood estimates, Schwartz Criterion (SC), Akaike's Information Criterion, and Likelihood Dominance Criterion (LDC), constructed by Pollak and Wales (1991), for the three systems indicate the superiority of ISNCES and QAIMDS specifications relative to NQM specification. They conclude that this outcome is related to the number of parameters that each model carries out. The NOM specification has more parameters than two other ones. In this article, Wang and Park investigate the effects of a reduction in predetermined variables, which are included in the group B equations on consumer welfare calculating the compensating variation (CV) and the equivalent variation (EV). The results indicate that a reduction in the meat and fish supply make Japanese consumers worse off. However, a reduction in the fish supply will affect consumer welfare more than a reduction in the meat supply.

Gao, Wailes, and Cramer (1996) present a different aspect of the mixed demand system. Regarding the governmental control of food in China, there are two different supplies of food in some urban areas in this country, rationed and non-rationed goods. Partial rationed food means that consumers can buy their allowance of food (quota) from the government at a lower price (subsidized price) and buy the rest of their needed supplies from the private market at a higher price. The researchers believe that for a market that includes two different types of supplies (and imposes two different demands), a mixed demand specification

is more appropriate by means of being consistent with theoretical outcomes. Rationed food products including pork, beef, eggs, and poultry are represented with a regular demand system of equations (price pre-determined), while non-rationed food including grain and edible oil are associated with an inverse demand system of equations (quantity pre-determined). They also consider fresh vegetables in the inverse demand system for the quick perishability of this product, as do other studies. The sample period covers January 1987 through December 1991. This study has been designed for three different specifications: a regular Rotterdam model, an inverse Rotterdam model, and a mixed Rotterdam model. It is also comprised of likelihood ratio tests, as Vuong introduced in his article (1989), to perceive which specification is more reliable. These tests reveal that a mixed demand system is a better specification relative to the two other models. Elaticities and flexibilities estimates demonstrate that income effects lead price effects. The government policy of rationing has a significant influence on demand for non-rationed food products. Price-price flexibilities of demand for non-rationed food commodities with respect to rationed foods indicate that these two groups of products are substitute goods. The same conclusion can be obtained from quantity-quantity elasticities of demand for rationed food with respect to non-rationed food. The authors conclude that these relations are theoretically consistent, since Chinese consumers will select the staple ration food products when the price of these foods is high in the private market. This consumer behavior causes the negative relations between these two groups of commodities.

The last article which will be reviewed in this section belongs to Brown and Lee (2006), "A Mixed Rotterdam Model." As mentioned, Moschini and Vissa (1993), Moschini and Rissi, (2006 and 2007), Wong and Park (2007) identify their mixed demand system through the conditional cost function, while in their study, Brown and Lee adopt Barten's (1992) fundamental matrix equations to specify the mixed Rotterdam demand system. This is the approach that is also applied in this study. Their primary goal is to demonstrate the relationship between the mixed demand system and its related regular and inverse demand functions. They conclude that the regular and inverse Rotterdam demand models are special cases of the mixed Rotterdam demand model. Having this knowledge, one can easily impose the same utility-based restrictions for mixed demand as regular or inverse demand. The interpretation of mixed demand coefficients is also

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straightforward. In the same study, they illustrate several mixed Rotterdam models with different restrictions in applications. To determine the effects of prices and quantities of fruits in each specification, Brown and Lee adopt the fruits annual data, such as per capita fresh table fruit consumption and their retail prices for the period from 1980 to 2000. Since all bananas and grapes consumed in the U.S. are imported, and fresh oranges and grapefruits consumed in the U.S are produced domestically, Brown and Lee believe that a mixed demand specification is appealing for this case. The two sets of demand equations considered in their study are: group "a," a set of inverse demand equations that include apples/pears, bananas, and grapes and group "b," a set of regular demand equations that is comprised of oranges and grapefruits. Their restricted mixed demand models are preference independent model block dependent model I, and block dependent model II. The two latter specifications are represented as level versions of mixed demand models. The coefficient and elasticities estimates indicate that all the coefficients for a preference independent model have the expected sign and are statistically significant. While the signs of all coefficients of the block dependent model I are the same as those for the preference independent model, the t value for several of the coefficients are lower in this model. The coefficients and elasticities estimates for the block dependent model II are similar to those for the block dependent model I, excluding the cross-group elasticity coefficients. A comparison between the block dependent model I and the block dependent model II reveals that to represent the fresh fruit demand model, one should consider some types of cross-group relationships. Regarding the likelihood ratio tests, they accept the block dependent model II as their final model.

The purpose of reviewing the mixed demand studies in this section is to give the readers some knowledge of this specification and to show in what condition of commodities market this model is appealing. This model will be discussed in more detail in the next chapter.

CHAPTER 3
MIXED DEMAND THEORETICAL ANALYSIS

This chapter introduces the theoretical concepts of the mixed demand theory, especially the mixed Rotterdam demand system. In brief, it provides details of the underlying economic theory, the prerequisite assumptions, and the econometric techniques applied to the model.

In applied economics, specifically in agricultural economics, a commodity can be processed and marketed in several forms. This type of commodity constitutes a group of products rather than only one product. For example, fruits can be marketed fresh, concentrate, and/or canned. In such instance, there may not be a unique relationship between the price and the quantity among all types of products within the group. This means that not all commodities within the group behave in the same way in the market. For instance, some products of the group may have short-term supply making their supply functions inelastic. Others, though, can be preserved and may have a longer-term supply, relative to the first products, making their supply functions upward-sloping. When all the products of a commodity are following the same price/quantity relations, a regular demand or an inverse demand function will be appropriated. However, when there is a particular type of product in a group, as mentioned, the question arises: How can a demand function for this particular type of good be traced? In 1965, Samuelson responded to this question, by positing that a mixed demand system is the most accurate model for such a commodity. An ordinary/regular demand system or an inverse demand system, which are the polar cases of the demand systems, present only one aspect of demand behavior: either the quantities consumed are a function of prices or the prices are a function of quantities demanded, respectively. They are not able to respond in a more complicated system of demand as evidenced by the above example. However, these two models have long been favorites for economic researchers. A mixed demand system as a third class of demand model (Moschini and Rizzi, 2006) is an alternative demand specification in consumer behavior theory. It is introduced by Samuelson (1965) and its theoretical framework is developed by Chavas (1984) and Cunha-e-Sa and Ducla-Soares (1999). Since this system is able to respond to both quantity and price dependent functions issues, it is appealing by providing added flexibility. While most of the consumer demand studies apply time series

data, which are aggregated data across households, Samuelson's mixed demand functions are not only proper specifications, but also provide a theoretical basis for this type of study (Chavas, 1984).

The mixed demand system of equations, like ordinary demand functions, can also be derived from the consumer utility maximization problem. The mixed set of demand functions contains both coefficients of an ordinary[7] demand system and of an inverse demand system (Barton, 1992). In the case of driving a mixed demand system, one needs to specify a mixed utility function. Samuleson believes this mixed model is neither a direct utility nor an indirect utility function, but holds the more general property of comprising both quantities and prices (Samuelson, 1965). Samuelson has named "a new fundamental function of both x's and y's" (x is the quantity of demand and y is the normalized price), the mixed utility function can be written as follows:

$$\phi(X) \text{ and } \Phi(Y) = -\phi(Y), \text{ with } U \equiv \phi(X) + \Phi(Y) \qquad \text{or} \qquad U = \phi(X) - \phi(Y) \qquad (3.1)$$

where the functions $\phi(X)$, direct utility, and $\Phi(Y)$, indirect utility, are dual functions. Therefore, the function "U" is a function of either the quantity set or the relative price set. In his paper, Samuelson explains that to obtain such a function: 1) a utility function should satisfy the regularity assumptions; 2) $x_i's$ are nonnegative; 3) a utility function $U = \phi(X) = \phi(x_1, x_2, ..., x_n)$ is a strictly convex set in the X space and a strictly monotonic increasing function of each of its arguments; 4) this utility function should be continuously twice differentiable; 5) and this utility function, $\phi(X)$, should have fewer utility if any good is zero than any set of utility $\phi(Z)$ when all goods are positive.

$$U(X;Y) = U(x_a, \bar{x}_b; \bar{y}_a, y_b) = \phi(x_{a1}, ..., x_{an}, \bar{x}_{b1}, ..., \bar{x}_{bm}) + \Phi(\bar{y}_{a1}, ..., \bar{y}_{an}, y_{b1}..., y_{bm}), \qquad (3.2a)$$

i=1,2,…,n   and   j=1,2,…,m

or

$$U(X;Y) = U(x_a, \bar{x}_b; \bar{y}_a, y_b) = \phi(x_{a1}, ..., x_{an}, \bar{x}_{b1}, ..., \bar{x}_{bm}) - \phi(\bar{y}_{a1}, ..., \bar{y}_{an}, y_{b1}..., y_{bm}), \qquad (3.2b)$$

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[7] As explained, an ordinary or a regular demand, known as Marshallian demand, is a function that the quantity of demand is a function of prices and household income.

i=1,2,…,n   and   j=1,2,…,m.

He states that by applying the negative sign for the indirect utility function, one is able to maximize the mixed utility function appreciating perfect symmetry property of direct and indirect utility functions. In a mixed utility function (equations 3.2), two special cases are expected. One will have a set of pure quantities if $j=0$, whereas one will have a set of pure prices if $i = 0$ (Samuelson, 1965). The latter case demonstrates a direct utility function while and the former illustrates an indirect utility function. To find the set of all n equilibrium points, one should maximize a total space of 2n-dimension of $(\bar{x}_{ai}, \bar{y}_{bj})$, with respect to $Y'X = 1$, where i=1, 2, …, n and j=1, 2, .., m (Samuelson, 1965).

$$MaxU \; (\; x, \bar{x}, \bar{y}, y \;) = 0 \qquad\qquad (3.3)$$
$$\scriptsize(x,y)$$

s.t. $Y'X = 1$.

By solving this optimization problem, two sets of the mixed demand will be obtained. The first equations represent the regular demand system, and the second equations represent the inverse demand system.

$$x_{ai} = x^i(\bar{y}_{a1},…, \bar{y}_{an}; \bar{x}_{b1},…, \bar{x}_{bm}) \qquad (i=1,…n) \qquad\qquad (3.4a)$$

$$y_{bj} = y^j(\bar{y}_{a1},…, \bar{y}_{an}; \bar{x}_{b1},…, \bar{x}_{bm}) \qquad (j=1,…m). \qquad\qquad (3.4b)$$

The term x_{ai} shows the quantity of good i which is the function of its own price, all other goods' prices, and the quantities of commodities that belong to the second subgroup. The term in the left hand side of the second system of equations, y_{bj}, illustrates the price of good i which is the function of the first subgroup's goods' prices, its own quantity, and the quantities of all other commodities that belong to the second subgroup.

A mixed demand system of equations has a close relationship with a conditional/rationed demand function (Chavas, 1984). Conditional demand functions have been illustrated with some applications to consumer rationing (Pollak, 1969; Deaton, 1981), non-market goods such as natural resources and

environmental goods and services (Cornes, 1980; Gueonerie, 1981), and the analysis of the impacts of leisure on consumption (Deaton and Muellbauer, 1980). The major difference between the mixed demand system and conditional/rationed demand system is that the market is not reaching to equilibrium points for all commodities when one applies the conditional demand system. For instance, consider that some goods are distributed as quotas in a society, meaning that, their allocation is independent of the market mechanism. Every individual has a fixed allotment and is not allowed to sell his/her quota. There is also not any addition of these products in the market. Accordingly, one can divide all commodities into two subgroups. The first group of products is allocated through the market mechanism, Q, and the second part is pre-allocated, Q^*. Then the individual preference can be associated with an ordinal utility function (Pollak, 1969). In this illustration, the utility function can be written as follows:

$U(q_1, q_2, ..., q_n)$.

To obtain the demand function through a utility maximization function, an additional constraint should be taken into account:

$$\sum_{i \in Q} p_i q_i = M \tag{3.5a}$$

$$q_i = q_i^* \qquad i \in Q^*, \tag{3.5b}$$

where M denotes the total expenditure on goods which are available in the market. The equation (2b) demonstrates the condition of the commodities subject to quota. After maximizing the utility function subject to these two constraints, the conditional demand function is:

$$q_i = f^{i,Q^*}(P_q, M, Q^*), \tag{3.6}$$

where P_q is the vector of market goods' prices and Q^*, as mentioned above, is the vector of pre-allocated commodities. The individual conditional demand function will hold all fundamental assumptions of an ordinary demand function, as long as the individual quota is fixed (Pollak, 1969). The conditional utility function can also be written as follows:

$$U(Q, Q^*) = U(q_1, q_2, ..., q_r, q_{r+1}^*, ..., q_n^*). \tag{3.7}$$

As evident, only market goods are involved in the optimization process and only market goods are participating in the budget constraint (equation 3.5a). In other words, only these commodities are consumed in an optimal point while the rationed commodities may not be. This is not the case in the mixed utility optimization process which will be explained in detail later in this chapter. In a mixed demand system, all goods are participating in the market mechanism to be allocated in the optimum way.

The mixed demand system can be proposed for the rationed goods if there is partial rationing in the society. The case illustrated here is an example of strict rationing. The difference between partial rationing and strict rationing is that, with strict rationing, consumers are not allowed to buy rationed goods (allotments) from the market, mentioned as one of the assumptions in the previous example. Partial rationing can be a subject for the mixed demand study (Gao et al., 1996), since consumers are not only able to buy rationed goods/quotas from the government's distribution system at a lower price, but are also able to buy extra provisions from the competitive market at a higher price. Accordingly, rationed goods are interacting in two different ways in the market; some part of their quantity is pre-determined and the government distribution system adjusts the price rather than market, while the remainder is of price pre-determined that participates in the market mechanism along all other non-rationed goods. For the price pre-determined part, the market will be cleared by adjusting the quantity. Gao et al. (1996) apply a mixed demand specification for the Chinese urban household by considering these assumptions. They deliberate an inverse demand system for the rationed part of the commodity and appreciate a regular demand system for the non-rationed part.

3.1. Mixed Demand Specification

Like a regular demand, a mixed demand system can be obtained through the utility maximization problem. The difference between a mixed utility function and a direct or indirect utility function is that a mixed utility function comprises the variables of both of these utility functions instead of only one. As indicated, in this instant, a mixed utility function is more flexible than a direct utility function which only subjects one direction of consumers' utilities.

Although the numbers of studies that have applied this model are rare, the variety of specifications used in these studies has been comparatively high. Mocshini and Vissa (1993), Moschini and Rissi (2006, 2007), and Wong and Park (2007) have obtained an empirical model for the mixed demand through the conditional cost function. Mixed Rotterdam Demand System, Stone-Geary Mixed Demand System, Normalized-Quadratic Mixed Demand System, Quadratic Almost Ideal Mixed Demand System (QAIMDS), and Nested Constant Elasticity of Substitution (NCES) are some examples of models that have been derived from this technique. Brown et al. (1993), Brown and Lee (2006), and Gao et al. (1996) parameterize this model via the primary utility functional form as Samuelson and Chavas analysis. The mixed Rotterdam demand system has been obtained by applying this method. Moschini and Vissa (1993, 2006) posit that neither a Flexible Functional Forms (FFFs) for the indirect utility functions will have a closed-form solution for the direct utility functions nor a more restricted representation of preferences will be able to implement a more straightforward way to obtain consistent estimations than the optimality condition equations. To parameterize an estimable mixed demand system, in addition to a decent knowledge of both direct utility and indirect utility function, a functional form with a closed form dual representation is needed (Samuelson, 1965; Chavas, 1984; Moschini, 1993). According to consumer demand theory, cost functions, indifference curves and utility functions should hold some properties to derive a demand function. After that parameters of such a demand system can be estimated. If these properties are satisfied, one can also apply the derivative properties to benefit from the existing relationship among equations of a demand system. If the observable variables for a direct utility function are available, which means the parameters of such a function can be defined through a consistent functional form by applying Hotelling-Wold's Identity, one is able to trace an inverse demand function. All other forms of demand systems can be derived through other identities and lemmas. The differential demand approach is able to satisfy all these properties. This approach does not need any algebraic specification of a direct utility function, an indirect utility function, or a cost function. The coefficients of the demand system that can be derived from this technique are not required to be constant. Parameterization of such a system is the last step to implement (Theil, 1987).

This study adopts the Brown and Lee parameterization (2006) to obtain the mixed demand system after deriving the general demand system through the differential approach. This model is known as the mixed Rotterdam demand system. Like a regular demand, a mixed demand system can also be achieved through the optimization problem:

$$\underset{q_a,\,p_b}{Max} \qquad z(\,q_a,\overline{q}_b,\overline{p}_a,p_b,y\,)=u(\,q_a,\overline{q}_b\,)-v(\,\overline{p}_a,p_b,M\,) \tag{3.8a}$$

$$s.t. \qquad \overline{p}'_a q_a + p'_b \overline{q}_b = M \tag{3.8b}$$

where the u(.) and v(.) are the direct and indirect utility functions, respectively; p'_a and p'_b are vectors of prices for the commodity group a and b, respectively; and q_a and q_b are the vectors of quantities consumed for the commodity group a and b, respectively. Consequently, the mixed utility function, z, is a monotonic increasing function of its arguments (Barten, 1989). By applying the Lagrangian expression, the optimum prices and quantities will be attained at the point at which the first order conditions equal zero,

$$L=u(\,q_a,\overline{q}_b\,)-v(\,\overline{p}_a,p_b,M\,)-\lambda(\,M-\overline{p}'_a q_a - p'_b \overline{q}_b\,), \tag{3.9a}$$

$$\frac{\partial z(\,q_a^*,\overline{q}_b,\overline{p}_a,p_b^*\,)}{\partial q_a}=\frac{\partial u(\,q_a^*.\overline{q}_b\,)}{\partial q_a}-\lambda\overline{p}_a=0 \tag{3.9b}$$

$$\frac{\partial z(\,q_a^*,\overline{q}_b,\overline{p}_a,p_b^*\,)}{\partial p_b}=-\frac{\partial v(\,\overline{p}_b,p_b^*\,)}{\partial p_b}-\lambda\overline{q}_b=0 \tag{3.9c}$$

$$\frac{\partial z(\,q_a^*,\overline{q}_b,\overline{p}_a,p_b^*\,)}{\partial \lambda}=\overline{p}'_a q_a + p'_b \overline{q}_b - M=0 \tag{3.9d}$$

or:

$$\frac{\partial u(\,q_a^*.\overline{q}_b\,)}{\partial q_a}=\lambda\overline{p}_a \tag{3.10a}$$

$$\frac{\partial v(\,\overline{p}_b,p_b^*\,)}{\partial p_b}=-\lambda\overline{q}_b \tag{3.10b}$$

$$\overline{p}'_a q_a + p'_b \overline{q}_b = M\,, \tag{3.10c}$$

where λ is the Lagrangian multiplier. This system includes "n+m+1" equations and unknown parameters; n equation belongs to (3.5a), m equations are related to (3.5b), and the last equation is the budget constraint (3.5c). Conditioning on the budget constraint, these "n+m+1" equations, obtained from first derivative of optimization/maximization of Lagrangian expression (equation 3.4), insure that the utility function is stationary. The second order condition, which is the second derivative of the optimization problem, guarantees that the stationary value is a maximum (Theil, 1975). After solving these three equations simultaneously, the result will be a mixed demand system:

$$q_a^* = q_a(\ \bar{p}_a, \bar{q}_b, M\ ) \tag{3.11a}$$

$$p_b^* = p_b(\ \bar{p}_a, \bar{q}_b, M\ ) \tag{3.11b}$$

$$\lambda = \lambda(\ \bar{p}_a, \bar{q}_b, M\ ). \tag{3.11c}$$

Equations (3.11a) and (3.11b) are the Marshallian mixed demands. Comparing a regular demand system and an inverse demand system with above mentioned equations (3.8) indicates that these two former equations are extreme cases of the mixed demand system. When all prices are exogenous, the equations (3.8) change to an optimization problem for a conditional regular demand system, and when all quantities are exogenous, the equations (3.8) becomes an optimization problem for a conditional inverse demand system of equations (Brown and Lee, 2006). In other words, the equations (3.11a) and (3.11c) are the first order condition for a conditional regular/ordinary demand system, and equations (3.11b) and (3.11c) are the first order condition for a conditional inverse demand system (Brown and Lee, 2006). This mixed demand system, which is obtained from the constrained optimization approach, like a direct utility maximization problem, satisfies the classic restrictions of consumer behavior theory. The budget restriction in the model meets the adding up property. As both ordinary/regular and inverse demand systems are satisfying the homogeneity condition, the regular demand function $q^* = q_a(\ \bar{p}_a, \bar{q}_b, M\ )$ is homogeneous of degree zero in p_a and M, and the inverse demand function, $p_b^* = p_b(\ \bar{p}_a, \bar{q}_b, M\ )$ is also homogeneous

of degree zero in p_a and M (Mocshini and Vissa, 1993). The mixed utility function, z(.), now can be written as follow:

$$z^M(\bar{q}_b,\bar{p}_a,M) = u[q_a(\bar{p}_a,\bar{q}_b,M),\bar{q}_b] = v[\bar{p}_a,p_b(\bar{p}_a,\bar{q}_b,M)].$$
(3.12)

3.2. Mixed Rotterdam Demand Parameterization

As mentioned in previous sections, to apply the mixed demand system for the practical determination with observed variables, one needs a dual flexible representation of preferences, since the solutions of optimality conditions (equations 3.10) are not feasible as general representations of preferences (Mocshini and Rizzi, 2007).

Following Brown and Lee, this study applies a log differential mixed demand system, known as mixed Rotterdam specification, to parameterize the demand function. To obtain the final parameterizations, the following steps should be taken. First a total differentiation of the mixed demands (3.11a) and (3.11b) is derived:

$$dq_a = (\frac{\partial q_a}{\partial p_a'})dp_a + (\frac{\partial q_a}{\partial q_b'})dq_b$$
(3.13a)

$$dp_b = (\frac{\partial p_b}{\partial p_a'})dp_a + (\frac{\partial p_b}{\partial q_b'})dq_b$$
(3.13b)

$$d\lambda = (\frac{\partial \lambda}{\partial p_a'})dp_a + (\frac{\partial \lambda}{\partial q_b'})dq_b.$$
(3.13c)

To simplify the form of the equations, the terms $\bar{p}_a$ and $\bar{q}_b$ are changed to p_a and q_b, respectively, while they still mean as exogenous variables. In the second step, the total differentiations of the first order conditions, equations 3.10, are taken into account:

$$\frac{\partial^2 u(q_a^*.\bar{q}_b)}{\partial q_a \partial q_a}dq_a + \frac{\partial^2 u(q_a^*.\bar{q}_b)}{\partial q_a \partial q_b}dq_b = \lambda dp_a + p_a d\lambda,$$
(3.14a)

$$\frac{\partial^2 v(\bar{p}_b,p_b^*)}{\partial p_b \partial p_b}dp_b + \frac{\partial^2 v(\bar{p}_b,p_b^*)}{\partial p_b \partial p_a}dp_a = -\lambda dq_b - q_b d\lambda,$$
(3.14b)

$$p_a'dq_a + q_a'dp_b + p_b'dq_b + q_b dp_b = dM \; . \tag{3.14c}$$

The two first equations can be rewritten as follows:

$$U_{aa}dq_a + U_{ab}dq_b = \lambda dp_a + p_a d\lambda \tag{3.15a}$$

$$V_{bb}dp_b + V_{ab}dp_a = -\lambda dq_b - q_b d\lambda \tag{3.15b}$$

where U_{aa}, U_{ab}, V_{bb}, and V_{ab} are the Hessian matrices. Rearranging these equations provides the new equations.

$$U_{aa}dq_a = \lambda dp_a - U_{ab}dq_b + p_a d\lambda \tag{3.16a}$$

$$V_{bb}dp_b = -\lambda dq_b - V_{ab}dp_a - q_b d\lambda \tag{3.16b}$$

$$p_a dq_a + q_a dp_b = dM - q_a dp_a - p_b dq_b \tag{3.16c}$$

or:

$$dq_a = \lambda U_{aa}^{-1}dp_a - U_{aa}^{-1}U_{ab}dq_b + U_{aa}^{-1}p_a d\lambda \tag{3.17a}$$

$$dp_b = -\lambda V_{bb}^{-1}dq_b - V_{bb}^{-1}V_{ab}dp_a - V_{bb}^{-1}q_b d\lambda \; . \tag{3.17b}$$

Then, after some manipulations, the following equations will be the differential mixed demand system with the nominal prices,

$$dq_a = \phi_{ab}^{-1}U_{aa}^{-1}p_a(\, p_a'dq_a + q_b'dp_b \,)+(\, \lambda U_{aa}^{-1} - \lambda\phi_{ab}^{-1}U_{aa}^{-1}p_a p_a'U_{aa}^{-1} + \phi_{ab}^{-1}U_{aa}^{-1}p_a q_b'V_{bb}^{-1}V_{ab} \,)dp_a +$$
$$(\, -U_{aa}^{-1}U_{ab} + \phi_{ab}^{-1}U_{aa}^{-1}p_a p_a'U_{aa}^{-1}U_{ab} + \lambda\phi_{ab}^{-1}U_{aa}^{-1}p_a q_b'V_{bb}^{-1} \,)dq_b, \tag{3.18a}$$

$$dp_b = \phi_{ab}^{-1}V_{bb}^{-1}q_b(\, p_a'dq_a + q_b'dp_b \,)+(\, -V_{bb}^{-1}V_{ab} - \lambda\phi_{ab}^{-1}V_{bb}^{-1}q_b p_a'U_{aa}^{-1} + \phi_{ab}^{-1}V_{bb}^{-1}q_b q_b'V_{bb}^{-1}V_{ab} \,)dp_a +$$
$$(\, -\lambda V_{bb}^{-1} - \phi_{ab}^{-1}V_{bb}^{-1}q_b p_a'U_{aa}^{-1}U_{ab} - \lambda\phi_{ab}^{-1}V_{bb}^{-1}q_b q_b'V_{bb}^{-1} \,)dq_b, \tag{3.18b}$$

where $\phi_a^{-1} = (\, p_a'U_{aa}^{-1}p_a \,)^{-1}$, $\phi_b^{-1} = (\, -q_b'V_{bb}^{-1}q_b \,)^{-1}$, and $\phi_{ab}^{-1} = \phi_a^{-1} + \phi_b^{-1}$. In this system of equations, dq_a and dp_b are endogenous variables that are determined in the market with any changes in exogenous variables, dp_a and dq_b. Brown and Lee (2006) have proven that this functional form satisfies the adding up condition and keeps the objective function (3.9a) unchanged at zero. To show how these properties are

satisfied, the equations (3.18) are recalled. The equation (3.18a) will be multiplied by the transpose matrix of p_a and equation (3.18b) will be multiplied by the transpose matrix of q_b.

$$
\begin{aligned}
p_a' * dq_a &= \phi_{ab}^{-1}U_{aa}^{-1}p_a(\, p_a'dq_a + q_b'dp_b\,) + (\lambda U_{aa}^{-1} - \lambda\phi_{ab}^{-1}U_{aa}^{-1}p_a p_a'U_{aa}^{-1} + \phi_{ab}^{-1}U_{aa}^{-1}p_a q_b'V_{bb}^{-1}V_{ab})dp_a + \\
&\quad (-U_{aa}^{-1}U_{ab} + \phi_{ab}^{-1}U_{aa}^{-1}p_a p_a'U_{aa}^{-1}U_{ab} + \lambda\phi_{ab}^{-1}U_{aa}^{-1}p_a q_b'V_{bb}^{-1})dq_b,
\end{aligned}
\tag{3.19a}
$$

$$
\begin{aligned}
q_b' * dp_b &= \phi_{ab}^{-1}V_{bb}^{-1}q_b(\, p_a'dq_a + q_b'dp_b\,) + (-V_{bb}^{-1}V_{ab} - \lambda\phi_{ab}^{-1}V_{bb}^{-1}q_b p_a'U_{aa}^{-1} + \phi_{ab}^{-1}V_{bb}^{-1}q_b q_b'V_{bb}^{-1}V_{ab})dp_a + \\
&\quad (-\lambda V_{bb}^{-1} - \phi_{ab}^{-1}V_{bb}^{-1}q_b p_a'U_{aa}^{-1}U_{ab} - \lambda\phi_{ab}^{-1}V_{bb}^{-1}q_b q_b'V_{bb}^{-1})dq_b.
\end{aligned}
\tag{3.19b}
$$

Adding equations (19) and rearranging, the new equation terminates to:

$$
p_a'dq_a - q_a'dp_a + q_b'dp_b + p_b'dq_b = dM,
\tag{3.20}
$$

this equation is exactly the total differentiation of the budget constraint, which proves the adding up condition for the mixed Rotterdam demand system. In order to apply this system (equations 3.19), a more compact system with the less parameters to be estimated is needed. Brown and Lee (2006) obtain this specification, in terms of matrices, by implementing the above mentioned equations (3.19),

$$
\begin{aligned}
[\,\widehat{p}_a\widehat{M}^{-1}\widehat{q}_a\,][\,\widehat{q}_a^{-1}dq_a\,] &= [\,\phi_{ab}^{-1}\widehat{p}_aU_{aa}^{-1}p_a\,](\,\widehat{M}^{-1}p_a'\widehat{q}_a\widehat{q}_a^{-1}dq_a + \widehat{M}^{-1}q_b'\widehat{p}_b\widehat{p}_b^{-1}dp_b\,) \\
&\quad + \lambda\widehat{M}^{-1}\phi_{ab}([\,\phi_{ab}^{-1}\widehat{p}_aU_{aa}^{-1}\widehat{p}_a\,] - [\,\phi_{ab}^{-1}\widehat{p}_aU_{aa}^{-1}p_a\,][\,\phi_{ab}^{-1}p_a'U_{aa}^{-1}\widehat{p}_a\,] \\
&\quad - [\,\phi_{ab}^{-1}\widehat{p}_aU_{aa}^{-1}p_a\,][\,\phi_{ab}^{-1}q_b'V_{bb}^{-1}\widehat{q}_b\,][\,-\lambda^{-1}\widehat{q}_b^{-1}V_{ab}\widehat{p}_a\,])[\,\widehat{p}_a^{-1}dp_a\,] \\
&\quad + \lambda\widehat{M}^{-1}\phi_{ab}(-[\,\phi_{ab}^{-1}\widehat{p}_aU_{aa}^{-1}\widehat{p}_a\,][\,\lambda^{-1}\widehat{p}_a^{-1}U_{ab}\widehat{q}_b\,] \\
&\quad + [\,\phi_{ab}^{-1}\widehat{p}_aU_{aa}^{-1}p_a\,][\,\phi_{ab}^{-1}p_a'U_{aa}^{-1}\widehat{p}_a\,][\,\lambda^{-1}\widehat{p}_a^{-1}U_{ab}\widehat{q}_b\,] \\
&\quad + [\,\phi_{ab}^{-1}\widehat{p}_aU_{aa}^{-1}p_a\,][\,\phi_{ab}^{-1}q_b'V_{bb}^{-1}\widehat{q}_b\,])[\,\widehat{q}_b^{-1}dq_b\,]
\end{aligned}
\tag{3.21a}
$$

$$
\begin{aligned}
[\,\widehat{q}_b\widehat{M}^{-1}\widehat{p}_b\,][\,\widehat{p}_b^{-1}dp_a\,] &= -[\,\phi_{ab}^{-1}q_bV_{bb}^{-1}q_b\,](\,\widehat{M}^{-1}p_a'\widehat{q}_a\widehat{q}_a^{-1}dq_a + \widehat{M}^{-1}q_b'\widehat{p}_b\widehat{p}_b^{-1}dp_b\,) \\
&\quad + \lambda\widehat{M}^{-1}\phi_{ab}([\,\phi_{ab}^{-1}\widehat{q}_bV_{bb}^{-1}\widehat{q}_b\,][\,-\lambda\widehat{q}_b^{-1}V_{ab}\widehat{p}_a\,] + [\,\phi_{ab}^{-1}\widehat{q}_bV_{bb}^{-1}q_b\,][\,\phi_{ab}^{-1}p_a'U_{aa}^{-1}\widehat{p}_a\,] \\
&\quad + [\,\phi_{ab}^{-1}\widehat{q}_bV_{bb}^{-1}q_b\,][\,\phi_{ab}^{-1}q_b'V_{bb}^{-1}\widehat{q}_b\,][\,-\lambda\widehat{q}_b^{-1}V_{ab}\widehat{p}_a\,])[\,\widehat{p}_a^{-1}dp_a\,] \\
&\quad + \lambda\widehat{M}^{-1}\phi_{ab}(-[\,\phi_{ab}^{-1}\widehat{q}_bV_{bb}^{-1}\widehat{q}_b\,] - [\,\phi_{ab}^{-1}\widehat{q}_bV_{bb}^{-1}q_b\,][\,\phi_{ab}^{-1}p_a'U_{aa}^{-1}\widehat{p}_a\,][\,\lambda^{-1}\widehat{p}_a^{-1}U_{ab}\widehat{q}_b\,] \\
&\quad - [\,\phi_{ab}^{-1}\widehat{q}_bV_{bb}^{-1}q_b\,][\,\phi_{ab}^{-1}q_b'V_{bb}^{-1}\widehat{q}_b\,])[\,\widehat{q}_b^{-1}dq_b\,],
\end{aligned}
\tag{3.21b}
$$

where, $\widehat{q}_a$ $\widehat{q}_b$ $\widehat{p}_a$ $\widehat{p}_b$ are diagonal matrices in which their diagonal elements are the elements of the vectors q_a, q_b, p_a, and p_b, and their off diagonal elements equal zero (Brown and Lee, 2006). The final equations, which provide more intuitive and adequate parameters, are given below:

$$w_{ai}Dq_{ai} = \theta_i DQ + \phi \sum_j (\theta_{ij} - \theta_i\theta_j - \theta_i \sum_s \gamma_s V_{ab}^{*sj})Dp_{aj} + \phi \sum_s (-\sum_j \theta_{ij}U_{ab}^{*js} + \theta_i \sum_j \theta_j U_{ab}^{*js} + \theta_i\gamma_s)Dq_{bs}, \qquad (3.22a)$$

$$w_{br}Dp_{br} = -\gamma_r DQ + \phi \sum_j (\sum_s \gamma_{rs} V_{ab}^{*js} + \gamma_r\theta_j + \gamma_r \sum_s \gamma_s V_{ab}^{*sj})Dp_{aj} + \phi \sum_s (-\gamma_{rs} - \gamma_r \sum_j \theta_j U_{ab}^{*js} - \gamma_r\gamma_s)Dq_{bs}. \qquad (3.22b)$$

The subscripts i and j stand for the elements (quantities or prices) of the commodity group "a" and subscripts r and s represent the elements of the commodity group "b." The terms w_{ai} and w_{br} on the left hand sides are the budget shares for the two commodity groups "a" and "b," respectively. For instance, the term w_{ai} demonstrates the budget share for good "i" in group "a."

$$w_{ai} = \frac{p_{ai}q_{ai}}{M} = \frac{p_{ai}}{M} * q_{ai} = \pi_{ai}q_{ai} \qquad (3.23a)$$

$$w_{br} = \frac{p_{br}q_{br}}{M} = \frac{p_{br}}{M} * q_{br} = \pi_{br}q_{br}. \qquad (3.23b)$$

The dependent variables (left hand side variables) for the regular demand and inverse demand equations are the quantity components of a change in budget share, dw_i, and price components of dw_i, respectively (Theil, 1987).

$$w_a = \frac{p_a q_a}{M} \qquad (3.24a)$$

$$dw_i = \frac{q_i}{M}dp_i + \frac{p_i}{M}dq_i - \frac{p_i q_i}{M^2}dM \qquad (3.24b)$$

$$dw_i = \frac{p_i q_i}{M}\frac{dp_i}{p_i} + \frac{p_i q_i}{M}\frac{dq_i}{q_i} - \frac{p_i q_i}{M}\frac{dM}{M} \qquad (3.24c)$$

$$dw_i = w_i d(\log p_i) + w_i d(\log q_i) - w_i d(\log M). \qquad (3.24d)$$

Equation (3.24d) implies that a change in the budget share of ith good is associated with the three components: 1) a change in the price of good i, 2) a change in the quantity of good i, and 3) a change in

income. As indicated, the price component and quantity component of the change in budget share are considered dependent variables in the mixed Rotterdam demand model. However, the quantity part is a dependent variable for an ordinary Rotterdam demand, and price part is a dependent variable for an inverse Rotterdam demand specification. In his 1987 book, Applied Demand Analysis, Theil calls the coefficients θ_{ij} and γ_{rs} calls as normalized price and quantity coefficients, respectively:

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\theta_{ij} + \sum_{r=1}^{m}\sum_{s=1}^{m}\gamma_{rs} = \sum_{i=1}^{n}\theta_i + \left(-\sum_{r=1}^{m}\gamma_r\right) = \sum_{i=1}^{n}\theta_i - \sum_{r=1}^{m}\gamma_r = 1. \tag{3.25}$$

The terms $\theta_i = \dfrac{\partial(p_{aj}q_{ai})}{\partial M}$ and $\gamma_r = \dfrac{\partial(p_{br}q_{br})}{\partial M}$ refer to the marginal budget shares (Theil, 1987) for the commodity group "a" and "b," while, as mentioned before, the expressions $w_{ai} = \dfrac{p_{ai}q_{ai}}{M}$ and $w_{br} = \dfrac{p_{br}q_{br}}{M}$ are the commodity group a and b's budget shares, respectively. Likewise, Brown and Lee (2006) have named these two terms as income and scale coefficients. For instance, the term θ_i means that the consumer will spend θ_i dollar on the good "i" in commodity group "a," if his/her income increases by one dollar. If the price of good "i" is considered as constant, then the marginal budget share can be rewritten as follows:

$$\theta_i = \frac{\partial(p_{aj}q_{ai})}{\partial M} = p_{aj}\frac{\partial q_{ai}}{\partial M} = \frac{p_{ai}q_{ai}}{M}\frac{\partial q_{ai}/q_{ai}}{\partial M/M} = \frac{p_{ai}q_{ai}}{M}\frac{\partial(\log q_{ai})}{\partial(\log M)} = w_{ai}\eta_{ai}, \tag{3.26}$$

where η_{ai} is the income elasticity. Therefore the coefficient θ_i is also the product of budget share and corresponding income elasticity. In other words, $\eta_{ai} = \dfrac{\theta_i}{w_{ai}}$ means that the income elasticity equals the ratio of the marginal share to its respective budget share (Theil, 1987). The same interpretation can be applied for the coefficient γ_r. Regarding the consumer behavior theory, for a normal good, the income coefficients, θ_i, should be positive while the scale coefficients, γ_r, must be negative.

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In a regular Rotterdam demand system, which was introduced by Theil (1987) the DQ is a finite-change version of the Divisia volume/quantity index. In an inverse Rotterdam demand system the DQ is a finite-change version of the Divisia price index (Barten and Bettendorf, 1989). However, the DQ for a mixed Rotterdam demand stands for the sum of both Divisia volume and Divisia price indices. Theil indicates that a decomposition of the change in income results in the sum of Divisia volume index and Divisia price index. In this study, the Divisia volume index represents a weighted average, i.e. budget shares, of the logarithmic quantity changes of n goods in the commodity group "a." In the same manner, the Divisia price index is a budget-share weighted average of the logarithmic price changes of the m goods in the commodity group "b." The Divisia price index determines the income effect on the demand for commodity group "r" when the m goods prices are changed,

$$DQ = \sum_{i=1}^{n} w_{ai} d(\log q_{ai}) + \sum_{r=1}^{m} w_{br} d(\log p_{br}) = \sum_{i=1}^{n} w_{ai} Dq_{ai} + \sum_{r=1}^{m} w_{br} Dp_{br}, \tag{3.27}$$

where $[w_{ai} d\log(q_{ai})] = \dfrac{p_a' \hat{q}_a}{M} \dfrac{dq_a}{\hat{q}_a} = \hat{M}^{-1} p_a' \hat{q}_a \hat{q}_a^{-1} dq_a$ and $[w_{ai} d\log(q_{ai})] = \dfrac{p_a' \hat{q}_a}{M} \dfrac{dq_a}{\hat{q}_a} = \hat{M}^{-1} p_a' \hat{q}_a \hat{q}_a^{-1} dq_a.$

This equation is the nominal price version of both the Divisia volume and the Divisia price indices. The definitions of other variables and parameters in equations (3.21) are shown as follows:

$$\hat{p}_a \hat{M}^{-1} \hat{q}_a = [\frac{p_{ai} q_{ai}}{M}] = [w_{ai}] \tag{3.28a}$$

$$\hat{q}_b \hat{M}^{-1} \hat{p}_b = [\frac{p_{br} q_{br}}{M}] = [w_{br}] \tag{3.28b}$$

$$\hat{q}_a^{-1} dq_a = [\frac{dq_{ai}}{q_{ai}}] = [d\log(q_{ai})] = [Dq_{ai}] \tag{3.28c}$$

$$\hat{q}_b^{-1} dq_b = [\frac{dq_{br}}{q_{br}}] = [d\log(q_{br})] = [Dq_{br}] \tag{3.28d}$$

$$\hat{p}_b^{-1} dp_b [\frac{dp_{br}}{p_{br}}] = [d\log(p_{br})] = [Dp_{br}] \tag{3.28e}$$

$$\widehat{p}_a^{-1} dp_a [\frac{dp_{ai}}{p_{ai}}] = [\, d\log(\,p_{ai}\,)] = [\, Dp_{ai}\,] \tag{3.28f}$$

$$U_{aa} = \frac{\partial^2 u}{\partial q_a \partial q_a'} \qquad U_{ab} = \frac{\partial^2 u}{\partial q_a \partial q_b'} \tag{3.28g}$$

$$V_{bb} = \frac{\partial^2 u}{\partial p_b \partial p_b'} \qquad V_{ab} = \frac{\partial^2 u}{\partial p_b \partial p_a'} \tag{3.28h}$$

$$\phi_{ab}^{-1} \widehat{p}_a U_{aa}^{-1} p_a = \frac{\lambda}{\phi M} \sum_{j=1}^{n} p_{ai} p_{aj} u^{ij} = [\,\theta_i\,] \quad \text{for i,j} = 1,\, 2,\, \dots,\, \text{n} \tag{3.28i}$$

$$\phi_{ab}^{-1} \widehat{p}_a U_{aa}^{-1} \widehat{p}_a = \frac{\lambda}{\phi M} p_{ai} p_{aj} u^{ij} = [\,\theta_{ij}\,] \qquad \text{for i,j} = 1,\, 2,\, \dots,\, \text{n} \tag{3.28j}$$

$$\phi_{ab}^{-1} \widehat{q}_b V_{bb}^{-1} q_b = \frac{\lambda}{\phi M} \sum_{s=1}^{m} q_{br} q_{bs} v^{rs} = [\,\gamma_r\,] \quad \text{for i,j} = 1,\, 2,\, \dots,\, \text{n} \tag{3.28k}$$

$$\phi_{ab}^{-1} \widehat{q}_b V_{bb}^{-1} \widehat{q}_b = \frac{\lambda}{\phi M} q_{br} q_{bs} v^{rs} = [\,\gamma_{rs}\,] \qquad \text{for i,j} = 1,\, 2,\, \dots,\, \text{n} \tag{3.28l}$$

$$\lambda \widehat{M}^{-1} \phi_{ab} = \frac{\lambda}{\widehat{M}} \phi_{ab} = \phi\,. \tag{3.28m}$$

The term ϕ is the reciprocal of the income elasticity of the marginal utility of income, which is

negative, since $U = [\,\frac{\partial^2 u}{\partial q_i \partial q_j}\,]$ is a symmetric negative $n \times n$ matrix and $\frac{\lambda}{\widehat{M}}$ is positive (Theil, 1987).

According to Theil's (1987), the term ϕ for a regular differential demand, such as the regular Rotterdam

demand model, equals:

$$\phi = \frac{\lambda}{\widehat{M}} \sum_{i=1}^{n} \sum_{j=1}^{n} p_i p_j u^{ij} \tag{3.28n}$$

so,

$$\phi_{ab} = \phi_a = \sum_{i=1}^{n} \sum_{j=1}^{n} p_{ai} p_{aj} u^{ij} = \widehat{p}_a U_{aa}^{-1} \widehat{p}_a\,. \tag{3.28o}$$

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The reason that $\phi_{ab} = \phi_a$ is that in a regular differential demand all prices are exogenous and there is only one commodity group. Since a mixed differential demand model includes more than one group of commodities (and, in this investigation two groups of goods), ϕ_{ab} will consist of the exogenous variables of both groups, p_a and q_b.

$$\phi_{ab} = \phi_a + \phi_b = (p'_a U^{-1}_{aa} p_a) + (-q'_b V^{-1}_{bb} q_b) \tag{3.28p}$$

Finally, the two terms U^{*js}_{ab} and V^{*sj}_{ab}, which are the cross-group coefficients (Brown and Lee, 2006), are defined below:

$$\lambda^{-1} \hat{p}^{-1}_a U_{ab} \hat{q}_b = U^{*js}_{ab} \tag{3.28q}$$

$$-\lambda^{-1} \hat{q}^{-1}_b V_{ab} \hat{p}_a = V^{*sj}_{ab} \tag{3.28r}$$

In equations (3.22a and 3.22b), coefficients θ_i, γ_s, ϕ, U^{*js}_{ab}, and V^{*sj}_{ab} are considered constants to be estimated. This system of mixed demand should hold some properties such as adding up, symmetry, homogeneity, and negativity conditions, and possession of these properties allows the model parameters to be estimated. To show that the present model in this study accommodates the adding up property, the definition of DQ is recalled.

$$DQ = \sum_i w_{ai} Dq_{ai} + \sum_r w_{br} Dp_{br}. \tag{3.29}$$

If one adds up equations (3.22) over "i" in commodity group "a" and over "r" in commodity group "b," then applies the equalities (3.28) the outcome will be as follows:

$$\sum_i w_{ai} Dq_{ai} + \sum_r w_{br} Dp_{br} = \sum_i \theta_i DQ - \sum_r \gamma_r DQ \tag{3.30a}$$

$$\sum_i w_{ai} Dp_{ai} + \sum_r w_{rs} Dq_{br} = (\sum_i \theta_i - \sum_r \gamma_r) DQ \tag{3.30b}$$

$$\sum_i w_{ai} Dp_{ai} + \sum_r w_{rs} Dq_{br} = DQ, \tag{3.30c}$$

where $\sum_i \theta_i - \sum_r \gamma_r = 1$. Equation (3.30c), provided above, can also be attained from the budget share constraint. Returning to the maximization problem, the budget constraint is presented as:

$$p'_a q_a + p'_b q_b = M,$$ (3.31)

the total differential of this constraint demonstrates the adding-up restriction:

$$p_a dq_a + q_a dp_a + p_b dq_b + q_b dp_b = dM.$$ (3.32)

Dividing both sides of the equation (3.32) by M and multiplying each part of the left hand side by the identity matrices pp^{-1} and qq^{-1} in select locations yields the equation below.

$$\frac{p'_a q_a}{M} q_a^{-1} dq_a + \frac{q'_a p_a}{M} p_a^{-1} dp_a + \frac{p'_b q_b}{M} q_b^{-1} dq_b + \frac{q'p_b}{M} p_{b\ b}^{-1} dp_b = \frac{dM}{M}$$ (3.33a)

$$\sum_i w_{ai} Dp_{ai} + \sum_r w_{rs} Dq_{br} = DM - \sum_i w_{ai} Dq_{ai} - \sum_r w_{br} Dp_{br},$$ (3.33b)

as shown above, $DM - \sum_i w_{ai} Dq_{ai} - \sum_r w_{br} Dp_{br} = DQ$,

so:

$$\sum_i w_{ai} Dp_{ai} + \sum_r w_{rs} Dq_{br} = DQ,$$ (3.34)

which is equation (3.27).

Applying the normalized coefficients imposes the homogeneity condition. The symmetry condition is satisfied by $\theta_{ij} = \theta_{ji}$ and $\gamma_{rs} = \gamma_{sr}$ which is constituted from the symmetry property of second partial derivatives matrices of the utility functions.

3.2.1 Mixed Rotterdam Demand under Preference Independence Assumption

The Rotterdam demand system that has been discussed so far has no restriction on consumers' utility functions. That is, the marginal utility of consumption of any goods, for example good i, is dependent on the consumption of good j, where i≠ j. Theil (1987) deliberates that the utility a consumer gains from consuming one commodity can be independent of consuming any other goods. In this situation, the total utility that a consumer attains from consuming all goods is:

$$Total u = \sum_{i=1}^{n} u_i(q_i), \tag{3.35}$$

where n is the number of the commodity which is consumed. This functional form is based on Preference Independence Assumption. That is, the marginal utility of consuming good i is independent of the consumption of good j, where i≠ j. Considering this restriction only for commodities within group a and group b, and not for commodities between these two groups, yields a preference independency for the direct and indirect utility functions in the general model equations (3.9).

$$u(q_a, \bar{q}_b) = \sum_{ai} u_{ai}(q_{ai}) + \sum_{ai} u_{br}(q_{br}) \tag{3.36a}$$

$$v(\bar{\pi}_a, \pi_b) = \sum_{ai} v_{ai}(\pi_{ai}) + \sum_{br} v_{br}(\pi_{br}). \tag{3.36b}$$

This restriction cause the cross-group coefficients, V_{ab}^{*sj} and U_{ab}^{*js}, in equations (3.21), to be zero. The presented mixed Rotterdam demand system will be changed as follows:

$$w_{ai} Dq_{ai} = \theta_i DQ + \phi \sum_{j}(\theta_{ij} - \theta_i \theta_j - \theta_i \sum_{s} \gamma_s V_{ab}^{*sj})Dp_{aj} + \phi \sum_{s}(-\sum_{j} \theta_{ij} U_{ab}^{*js} + \theta_i \sum_{j} \theta_j U_{ab}^{*js} + \theta_i \gamma_s)Dq_{bs},$$

$$w_{ai} Dq_{ai} = \theta_i DQ + \phi \theta_i(Dp_{aj} - \sum_{j} \theta_j Dp_{aj} + \sum_{s} \gamma_s Dq_{bs}) \tag{3.37a}$$

$$w_{br} D\pi_{br} = -\gamma_r DQ + \phi \sum_{j}(\sum_{s} \gamma_{rs} V_{ab}^{*js} + \gamma_r \theta_j + \gamma_r \sum_{s} \gamma_s V_{ab}^{*sj})Dp_{aj} + \phi \sum_{s}(-\gamma_{rs} - \gamma_r \sum_{j} \theta_j U_{ab}^{*js} - \gamma_r \gamma_s)Dq_{bs},$$

$$w_{br} Dp_{br} = -\gamma_r DQ - \phi \gamma_r(Dq_{br} - \sum_{j} \theta_j Dp_{aj} + \sum_{s} \gamma_s Dq_{bs}), \tag{3.37b}$$

where U_{ab}^{*js} and V_{ab}^{*sj} equal zero. All steps of these processes are shown in appendix I.

3.2.2. Mixed Rotterdam Demand Elasticity

Elasticity is an important concept in consumer choice theory. In many investigations the interpretation of elasticity estimates are more important than coefficient estimates. In general, the elasticity is expressed as a degree of the responsiveness of a function to change(s) in parameter(s). For a regular (Marshallian) demand, two major elasticities are defined: the own or cross price elasticity of demand and

the income elasticity of demand. The price elasticity of demand measures the percentage change in demand due to a 1% change in the own-price or price of another good (cross-price).

$$\varepsilon_{ij} = \frac{\%\Delta q_i}{\%\Delta p_j} \quad \text{or} \quad \varepsilon_{ij} = \frac{\log(q_i)}{\log(p_j)} \qquad \begin{cases} i = j \\ i \neq j \end{cases} \qquad \begin{cases} own - price - elasticity \\ cross - price - ealsticity \end{cases} . \tag{3.38}$$

Income elasticity of demand is the percentage change in the quantity of demand as a result of a 1% change in the consumer's income:

$$\eta_{q,I} = \frac{\%\Delta q}{\%\Delta I} . \tag{3.39}$$

Flexibility consideration is described in the same way as elasticity, but elasticity is used for regular demand while flexibility consideration is used for inverse (Hicksian) demand functions. However, these two concepts are not reciprocals of each other, except in certain conditions (Houck, 1965). Huang (2006) states the price flexibilities are theoretically the inverse of the price elasticities, but are not inverses of one another statistically. A mixed demand system of equations contains both regular and inverse demand equations; therefore, both elasticity and flexibility measurements are in consideration in this study. As explained in previous sections, the mixed Rotterdam demand specification's variables are in form of log changes. This characteristic makes the computation of elasticities and flexibilities straightforward. It is important to mention that in a mixed demand system of equations, independent variables include prices and quantities, rather than containing only prices or quantities. In this instance, the elasticities for regular demand equations consist of elasticity of prices and quantities. The inverse demand equations also comprise price and quantity flexibilities. To drive the elasticity and flexibility of demand for the equations (3.37), the following steps must be performed:

equation (3.37a): $\qquad w_{ai} Dq_{ai} = \theta_i DQ + \phi\theta_i (Dp_{aj} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs})$

$$Dq_{ai} = (\theta_i / w_{ai})DQ + (\phi\theta_i / w_{ai})(Dp_{aj} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs}), \tag{3.40}$$

equation (3.37b): $\qquad w_{br} Dp_{br} = -\gamma_r DQ - \phi\gamma_r (Dq_{br} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs})$

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$$Dp_{br} = (-\gamma_r / w_{br})DQ - (\phi\gamma_r / w_{br})(Dq_{br} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs}). \tag{3.42}$$

At this step, there are two different approaches to define elasticity. One can consider DQ as a variable (Brown and Lee, 2006) or assume that it is constant (Theil, 1987). This study follows Theil's definition, which assumes DQ is constant. Accordingly, the price and quantity elasticities and flexibilities of demand for the group a and b commodities are as follows:

1) own-price elasticities for group a commodities:

$$\varepsilon_{ii} = \frac{d\log(q_{ai})}{d\log p_{ai}} = \frac{Dq_{ai}}{Dp_{ai}} = \frac{\phi}{w_{ai}}(\theta_i - \theta_i * \theta_i) = \frac{\phi}{w_{ai}}(\theta_i - \theta_i * \theta_i), \tag{3.41a}$$

2) cross-price elasticity for group a commodities:

$$\varepsilon_{ij} = \frac{d\log(q_{ai})}{d\log p_{aj}} = \frac{Dq_{ai}}{Dp_{aj}} = \frac{\phi}{w_{ai}}(-\theta_i * \theta_j), \tag{3.41b}$$

3) quantity elasticity for group a commodities:

$$\delta_{ij} = \frac{d\log(q_{ai})}{d\log q_{bs}} = \frac{Dq_{ai}}{Dq_{bs}} = \frac{\phi}{w_{ai}}(\theta_i * \gamma_s), \tag{3.41c}$$

4) price flexibility for commodity group b:

$$\varsigma_{ri} = \frac{d\log(p_{br})}{d\log p_{ai}} = \frac{Dp_{br}}{Dp_{ai}} = \frac{\phi}{w_{br}}(\gamma_r * \theta_i), \tag{3.43a}$$

5) own-quantity flexibility for commodity group b:

$$\varsigma_{rr} = \frac{d\log(p_{br})}{d\log q_{br}} = \frac{Dp_{br}}{Dq_{br}} = -\frac{\phi}{w_{br}}(\gamma_r + \gamma_r * \gamma_r), \tag{3.43b}$$

6) cross-quantity flexibility for group b commodities:

$$\varsigma_{rs} = \frac{d\log(p_{br})}{d\log q_{bs}} = \frac{Dp_{br}}{Dq_{bs}} = -\frac{\phi}{w_{br}}(\gamma_r * \gamma_s). \tag{3.43c}$$

The income and scale elasticities/flexibilities for both commodity groups a and b are also taken into account. As explained earlier in this chapter, the income elasticity equals the ratio of the marginal share to its respective budget share (Theil, 1987).

$$\eta_{ai} = \frac{\theta_i}{w_{ai}}. \tag{3.44}$$

However, Brown and Lee (2006) have defined the income elasticities for both commodity groups in different ways. It seems their formulation is more related to a degree of change in a selected country imports with respect to the imports bundle price change, rather than as income and quantity (for inverse equations income and price) responsiveness. Therefore, in this study the income elasticity and flexibility for both groups are defined as follows:

$$\eta_{ai} = \frac{\theta_i}{w_{ai}}, \tag{3.45a}$$

$$\eta_{br} = \frac{-\gamma_r}{w_{br}}. \tag{3.45b}$$

The adding up constraint in the mixed Rotterdam demand model means that consumers are spending all of the proportion of their income allocated for shrimp products on these productions. In other words, they do not save or allocate some of this proportion for other purposes. A mathematical illustration of this condition states that the sum of all shrimp products' marginal shares for a consumer should be equal to one. The mixed Rotterdam model is associated with two marginal share coefficients; one for regular demand equations (θ_i) and another for the inverse demand equations ($-\gamma_r$). Therefore, the following statement refers to the mathematical solution of this restriction.

$$\sum_i \theta_i + \sum_r (-\gamma_r) = 1. \tag{3.46}$$

Consequently, the budget share weighted average of the income elasticities also sum to unity (Theil, 1987):

$$\eta_{ai} = \frac{\theta_i}{w_{ai}}, \qquad \theta_i = w_{ai}\eta_{ai} \tag{3.47a}$$

$$\eta_{br} = \frac{-\gamma_r}{w_{br}}, \qquad -\gamma_r = w_{br}\eta_{br} \tag{3.47b}$$

so,

$$\sum_i \theta_i + \sum_r (-\gamma_r) = 1, \qquad \sum_i w_{ai}\eta_{ai} + \sum_r (w_{br}\eta_{br}) = 1. \tag{3.47c}$$

The income elasticity can be positive or negative. A positive income elasticity of demand means that there is a direct relation between a consumer's income and her/his quantity of demand. In other words, as income increases the quantity of demand also increases. A negative income elasticity of demand implies that an increase in income will lead to a decrease in consumption (quantity of demand), an inverse relation. These types of goods are refers to as inferior. For a normal good, the income elasticity of demand will be between zero and one. However an income elasticity of demand greater than one is associated with luxuries.

The scale elasticity and flexibility for commodity groups a and b are also defined as follows:

$$\delta_a = \sum_j \delta_{ij}, \tag{3.48a}$$

$$\varsigma_b = \varsigma_{rs} + \varsigma_{rr} = \sum_s \varsigma_{rs}. \tag{3.48b}$$

In this study, the income elasticity of regular demand presents the relationship between the U.S. income/expenditure on shrimp products and the quantity of imports from each country, separately, as they are the endogenous variables for the regular demand equations. Income elasticities of the inverse demand equations are implying the relationships between the American income/expenditure and the Gulf dockside prices. In contrast, the scale flexibility, which is called scale elasticity in mixed demand, only demonstrates the scale expansion of an increase in income. So a proportion of consumption will be held constant in this estimation. These two elasticity demonstrations are described below. This shows the effect of a change in income on the consumption of two goods, q_1 and q_2. At point q^1 the consumer is at an optimal point and consumes q_1^0 and q_2^0.
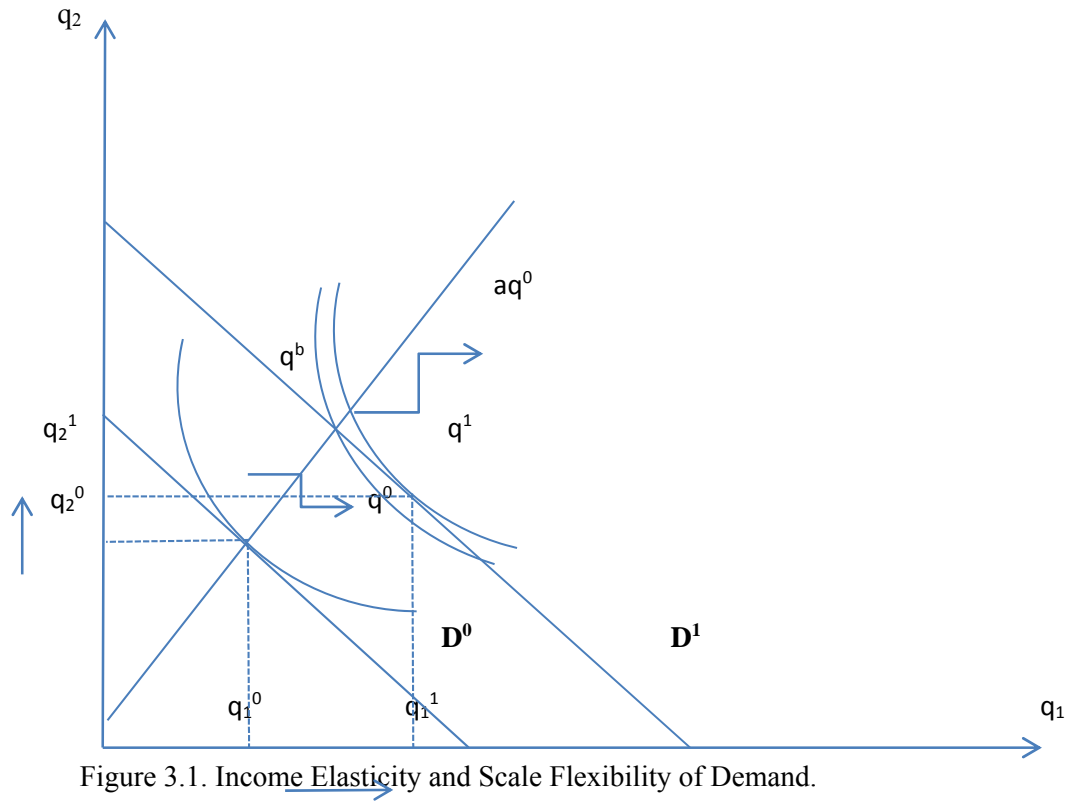
Figure 3.1. Income Elasticity and Scale Flexibility of Demand.

When income increases the consumer will consume more of both goods and his/her new optimal point changes. Now he/she consumes q_1^1 and q_2^1 of each good. He/she is going from point q^0 to q^1. The effect of income is associated with two changes: a move from q^0 to q^b and a move from q^b to q^1. A move from q^0 to q^b illustrates the scale expansion, while a move from q^b to q^1 shows the proportion change. But for infinite changes we show the effect of an increase in income from "q^0" to "aq^0" and from "aq^0" to "q^1." For the infinitesimal changes the difference between these two decompositions can be negligible. Therefore, the income elasticity demonstrates both effects, from "q^0" to "aq^0" and from "aq^0" to "q^1," while the scale elasticity only shows the effect of scale expansion that moves from one preference indifference curve to another one, from q^0 to aq^0 (Park and Thurman, 1999). The substitution effect is the move along the same indifference curve, from "aq^0" to "q^1." In practice, it can be shown as a move from "q^0" to "aq^0" and from "aq^0" to "q^1."

In only one condition, scale effect and proportion effect, which show the difference between scale elasticity and income elasticity, will be equal when the preferences are homothetic. This is illustrated below.
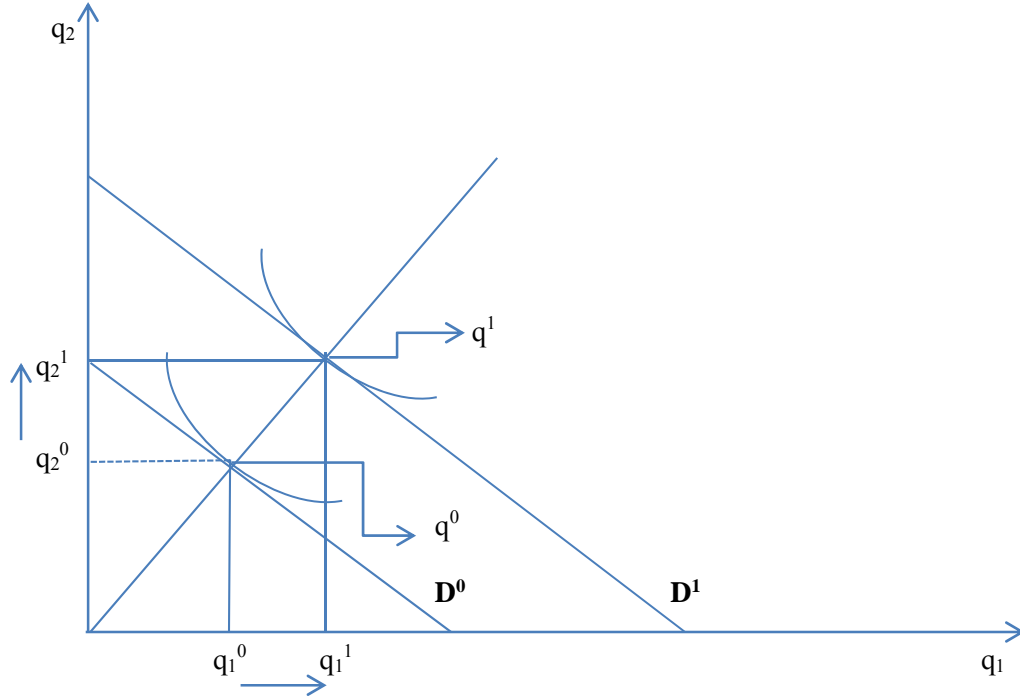
Figure 3.2. Income Elasticity and Scale Flexibility of Demand for Homothetic Preferences.

3.3. Mixed Rotterdam Demand Econometrics Model

To come to any expected quantitative results, an econometric specification of the mixed Rotterdam demand system that was introduced in the previous section is needed. Theil (1987) posits that the Rotterdam demand system is a finite-change version of a differential demand system which is in terms of infinitesimal changes. His regular Rotterdam demand system is defined as:

$$\overline{w}_{it}Dq_{it} = \theta_i DQ_t + \sum_{j=1}^{n} v_{ij}(Dp_{jt} - Dp'_t),$$ (3.49)

where $Dx_t = \log x_t - \log x_{t-1}$; t=time, for any positive variable x, $\overline{w}_{it} = \dfrac{w_{i,t-1} + w_{it}}{2}$, and $DQ_t = \sum_i \overline{w}_{it}Dq_{it}$.

In this instance, a subscript t should be added to the mixed Rotterdam demand system, equations (3.19). It

is noticeable that $D\mathcal{Q}$ in Theil's equation differs from $D\mathcal{Q}$ introduced in equations (3.27), since Theil's system of equations represents a regular Rotterdam demand system while this paper is concentrated on the mixed Rotterdam demand system. Therefore, the equations below are empirical applications, in the form of econometric specification, of the presented mixed Rotterdam demand model:

$$\overline{w}_{ai} Dq_{ai} = \theta_i DQ + \phi \theta_i (Dp_{aj} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs}) + \varepsilon_{ait} \tag{3.50a}$$

$$\overline{w}_{br} Dp_{br} = -\gamma_r DQ - \phi \gamma_r (Dq_{br} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs}) + \varepsilon_{brt} , \tag{3.50b}$$

where the subscripts t imply to the Theil's definitions. That is, a discrete changes from period t-1 to t. The terms $\overline{w}_{ait}$ and $\overline{w}_{brt}$ are the arithmetic average of $w_{ai,t-1}$ and $w_{ai,t}$ and $w_{br,t-1}$ and $w_{br,t}$, respectively. The disturbance terms, ε_{ait} and ε_{brt} are represented as the stochastic process of the econometric model. All other variables and parameters are as defined in previous sections.

CHAPTER 4
EMPIRICAL RESULTS AND DISCUSSION

As discussed in the previous chapters, the mixed Rotterdam demand system has been adopted to analyze the determinants of the U.S. shrimp industry. In this study, it is believed that the U.S. shrimp market's structure consists of two subsystems of equations which are known as reduced form equations (Barten, 1992).

In general, two different shrimp products are supplied in the U.S. market; domestically produced shrimp and imported shrimps. As indicated, the Gulf of Mexico produces more than 80% of the domestic shrimp productions. Historical data illustrates that the volume of Gulf landings has been almost constant during the last decades. In this condition, it is assumed that the equilibrium should be characterized by predetermined quantities with prices adjusting to clear the market (Moschini 1993). An inverse demand system is a typical representative of this market.

In contrast, the supply of imported shrimp has increased every year since the 1980s. There are three major shrimp importers in the international market: Japan, United States of America, and the European Union (FAO, 2009). Japan, U.S., and EU have consumed 25%, 48%, and 17% of the world frozen cultured shrimp exports in the early 2000s, respectively, which is a total of more than 90 percent of the world's farming shrimp exports (FAO, 2009). The farming shrimp producers are flexible to export their productions to the country/countries in which the prices are higher. The historical data illustrates that whenever a country imposes some regulations to import the shrimp products, the farming shrimp producers are diverting their exports from this county to other countries in which there are no or less restrictions. As an example, Cato and Santos's 2000 study demonstrates that Bangladesh could reduce the cost of the EU ban on its farmed shrimp producers by reallocating a large part of their productions toward the U.S. and Japan. In this instance, the farming cultured shrimp exporters are gaining advantage from shrimp market flexibility among these three major international exports markets. In such a condition, it is believed that, with a given set of prices, the quantities are adjusted to clear the market (Barten, 1989). While the domestic shrimp products and imports do not have the same market structure, it seems that a mixed demand system is an

appropriate model for this market, which consists of polar forms, regular and inverse demand systems. This study preforms a Rotterdam specification for the mixed demand system. The detailed explanation of the model, its application, and results are presented in this chapter as follows. First, data descriptions are presented. Next, the precision of the ITSUR technique and adequacy of the parameter estimates under this method are introduced. In the final section, the interpretation of parameter and elasticity estimates is considered.

4.1. Data

The mixed Rotterdam demand system is estimated using time series data for U.S. shrimp imports and Gulf of Mexico shrimp landings quantities and prices. Imports raw data have been gathered form the National Marine Fisheries Statistics (NMFS) website. Raw data for Gulf of Mexico shrimp landings have been provided directly from NMFS. The data for U.S. imports consist of eight countries including Thailand, Vietnam, China, India, Indonesia, Ecuador, Mexico, and a final category includes all other exporter countries. Demand for Gulf shrimp are specified by size of shrimp with three sizes (large, medium, and small) considered.

National Marine Fisheries Statistics reports the quantities of imports by product forms and countries in kilogram measurement. To be compared, the quantities of imports were adjusted to the headless shell-on volume applying convergence criteria reported in NMFS annual statistics reports. Then the kilogram volumes are converted to the pound volumes by dividing 0.453592. The NMFS Gulf of Mexico raw data for shrimp landings are also reported in the eight sizes which are aggregated to the three sizes, representing large, medium, and small sizes, by adding the first three sizes, then second three sizes, and then last two sizes together. To have the price per pound, the dollar values in both shrimp imports and landings reports are divided by the pound volumes. The U.S. imports from the various countries are modeled in a quantity dependent framework, while, the Gulf of Mexico landings has been modeled in a price dependent framework. The data stand for 1995(1) and ends for 2010(4). Appendix II illustrates the model variables and their definition.

The properties of the data are shown in the next two tables. Table 4.1 illustrates the summary statistics for the U.S. shrimp imports and Gulf landings. Table (4.2) demonstrates the quantity component share of each country and landings in total expenditure over the period of study.

Table 4.1. U.S. Shrimp Imports and Gulf of Mexico Landings Summary
Statistics, 1995(1)-2010(4).

Variable	N OBS	Mean Million (LB)	Std Dev Million (LB)	Minimum Million (LB)	Maximum Million (LB)
Chi_PO	183	8.43	7.93	0.36	36.46
Ecu_PO	183	9.45	3.60	2.66	16.99
Indi_PO	183	6.25	2.87	2.05	17.30
Indo_PO	183	7.97	6.27	0.61	25.27
Mex_PO	183	6.06	5.83	0.12	25.56
Thi_PO	183	38.88	17.96	9.85	83.7
Vie_PO	183	7.25	6.09	0.04	22.79
Other_PO	183	22.10	8.54	9.67	61.03
L1_PO	183	2.40	1.48	0.40	6.86
L2_PO	183	3.06	2.64	0.44	14.24
L3_PO	183	6.46	5.72	0.36	25.13

Table 4.2. U.S. Shrimp Imports and Gulf of Mexico Landings Share
In Total Income and their Summary Statistics, 1995(1)-2010(4).

Variable	N	% Share	Std Dev	% Min	% Max
W_Chi	183	4.65	0.035	0.37	16.55
W_Ecu	183	9.76	0.061	1.67	28.87
W_Indi	183	5.74	0.028	1.61	14.33
W_Indo	183	7.23	0.046	0.91	22.25
W_Mex	183	8.08	0.061	0.23	23.47
W_Thai	183	28.57	0.055	10.91	42.06
W_Vie	183	7.25	0.049	0.13	17.04
W_Other	183	18.63	0.059	6.29	42.53
W_L1	183	3.62	0.014	0.92	07.14
W_L2	183	2.86	0.019	0.45	11.44
W_L3	183	3.61	0.035	0.19	17.32

As table 4.2 shows, Thailand is associated with (28.57%), the highest percent quantity component share in the budget share changes through the first month of 1995 to April 2010. The total quantity component share of the seven countries named in this study is 78.53%, which is more than four times the sum of all Other Countries share (18.63%), which are not included in this model directly. The U.S. domestic shrimp products component shares, Gulf landings, are only 10.09% which is the least quantity component share.

4.2. Model Accuracy, Iterated Seemingly Unrelated Method

A general Rotterdam mixed demand system is introduced in the literature review and methodology sections. As previously mentioned, to apply such a system some restrictions should be imposed; adding-up, homogeneity, and symmetry restrictions are some examples. The system of equations that comprises this study also contains two more constraints along with all other restrictions. Those two limitations include the preference independence condition in both direct and indirect utility functions (Brown and Lee, 2006). As a result, the following system of demand equations is taken into account:

$$w_{ai} Dq_{ai} = \theta_i DQ + \phi \theta_i (Dp_{aj} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs})$$ (4.1)

$$w_{br} Dp_{br} = -\gamma_r DQ - \phi \gamma_r (Dq_{br} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs}) .$$ (4.2)

For empirical application purpose for the U.S. shrimp market demand, the mixed Rotterdam system is composed of eleven equations. As the mixed Rotterdam specification requires imposing adding up restriction in the data, to avoid having singularity problem for the contemporaneous error covariance matrix, the last equation which is demand equation for the Gulf small size shrimp, L3, randomly, is excluded prior to estimation. The estimates of the parameters are invariant to the deleted equation. The Gulf small size shrimp demand parameter can be obtained by applying an adding-up restriction or re-estimating the system by dropping a different equation, randomly.

Dependent variables for the first group of equations of this system (group equations 4.1), which are the quantity component of the change in budget share; stand for the budget share times the log difference

of quantity of imports. The dependent variables for the second group of equations (group equations 4.2), which are the price component of the change in budget share, are the budget share times the log difference of domestic landings' prices. The log difference of quantities and prices are comprised as the finite-change of the differential demand system. It is assumed that for infinitesimal changes a differential approach (continuous change) and an arithmetic difference (discrete change) almost result in the same way. To estimate this system of equations' parameters an Iterated Seemingly Unrelated technic is adopted using the SAS software package.

Primary to the estimation process, two conditions should have been taken into account. As common in most time series analyses, the serial correlation and seasonality problems in the estimated residuals are being concerned. The imports and landings data are displayed seasonality patterns, so that the monthly data eleven seasonal dummy variables are comprised in every equation of the system. The last month's (December) dummy variable has been dropped to avoid the dummy variable trap, the full correlation matrix of variables. To detect the presence of autocorrelation in the residuals from the regression analysis the t-test are applied. For the t statistic test, each equation of the model is first estimated by OLS (equation by equation); next, OLS residuals, obtained from the first step are regressed on all exogenous variables and the first and second lagged residuals (u_{t-1} and u_{t-2}). The parameters of these equations (ρ_1 and ρ_2) are the coefficients of the autoregressive equations (4.3). Therefore, the t statistics of these parameters (ρ_1 and ρ_2) are equivalent to the t statistics for the coefficient estimates of the autoregressive equations.

$$u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + e_t \qquad\qquad (4.3a)$$

$$\widehat{u}_t = \widehat{\rho}_1 u_{t-1} + \widehat{\rho}_2 u_{t-2} . \qquad\qquad (4.3b)$$

The t-statistics demonstrate that some equations suffer from first order autocorrelation. The advantage of this technique is that it allows one to detect the serial correlation problem even in models in that use non-strictly exogenous explanatory variables (Wooldrige, 2008). Along with this method, a Durbin Watson test statistic is also performed. The Durbin Watson test statistic for AR(1) is also a valid test for

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this model, since the DQ is considered as constant (Theil, 1987) in the Rotterdam specification. Therefore, it is assumed that there is no lagged dependent variable in any equation of the model.

$$d = \frac{\sum_{t=2}^{T}(\hat{u}_t - \hat{u}_{t-1})^2}{\sum_{t=1}^{T}\hat{u}_t^2}, \quad \text{(for t and k-1 d.f.)} \tag{4.4}$$

where T is the number of periods/observations and $e = y_t - \hat{y}_t$. For each equation of the mixed Rotterdam demand system, a null hypothesis test, implying the error terms are not serially correlated is constructed against the alternative that indicates they follow a first order autocorrelation process. The DW tests results are shown a first order autocorrelation in some demand equations of the system, as t-test statistic results constructed above are revealed. After considering AR(1) correction process for all demand equations in the same manner, in addition to a trend variable, the second round Durbin Watson test has been illustrated an acceptable results, as shown below.

Table 4.3. Test Statistics of Serial Correlation for Mixed Rotterdam Demand System.

Equation	DF Model	DF Error	SSE	MSE	Root MSE	Durbin Watson
WdC_PO	15.1	167.9	0.0502	0.0003	0.0173	1.49
WdE_PO	15.1	167.9	0.0595	0.0004	0.0188	2.28
WdIi_PO	15.1	167.9	0.0419	0.0003	0.0158	1.95
WdIo_PO	15.1	167.9	0.0385	0.0002	0.0151	2.36
WdM_PO	15.1	167.9	0.1670	0.0010	0.0315	2.05
WdT_PO	15.1	167.9	0.2103	0.0013	0.0354	2.09
WdV_PO	15.1	167.9	0.0763	0.0005	0.0213	1.93
WdO_PO	15.1	167.9	0.1382	0.0008	0.0287	1.90
WdL1_PPP	15.1	167.9	0.0004	0.0000	0.0016	1.75
WdL2_PPP	14.1	168.9	0.0006	0.0000	0.0019	1.76

Durbin Watson lower and upper bounds of critical value, d_L and d_U, for the number of variables equal to 20 and 150 degrees of freedom at a 5% level of significant are 1.443 and 2.040, respectively. To compare these critical values with the d statistic of every equation, the above rules are considered. A

comparison of Durbin Watson statistic estimations and critical values illustrate that only the Ecuador and Indonesia's imports demand equations are falling into the inconclusion zone.

The Lagrange Multiplier test, which is known as the Breusch-Godfrey test is an alternative to the t-test and DW test. This statistic is useful for identifying serial correlation for the first and higher order autocorrelation. However, it has two important disadvantages; 1) the LM test is a large sample test, 2) while it tests for serial correlation of both AR(p) and MA(q) forms, it is not able to identify which one is the cause of autocorrelation if it is detected.

As indicated, the AR(1) correction for the error covariance matrix is imposed after detrending the observations. The autoregressive correlation may have been overestimated[8] if the data demonstrates an upward or downward trend (Wooldrige, 2008). An upward time trend has been identified in imports observations, a common tendency in time series data. Existence of the time trend in some variables may lead to the conclusion that these variables are correlated. In fact, the reason is that these variables are growing over time for some reasons that are part of the model's unobserved factors. An exponential trend is comprised in the equations of system, because the imports have almost been shown a constant average grow rate from period to period.

To evaluate the performance of the model, after correcting for the first order autocorrelation problem and estimation of model parameters a Monte Carlo simulation has been constructed. The simulation process was performed from 2000 to 2011 and it is repeated 2000 times. The simulation method helps determine whether the structural specification of the model is reasonable and if the estimated coefficients make sense. There are also some methods of resampling data such as Bootstrapping and Jackknife. In the resampling technique, the simulated samples are drawn from the existing sample of data, which are applied for the study, while in a Monte Carlo simulation the data are generating from a theoretically defined process. Consequently, in resampling, for example, bootstrapping, there is no control

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[8] This issue refers to deterministic trends in the data, not stochastic trends. Author investigated whether the variables of the model which is studying here have the unit roots or stochastic trends. The unit root test has rejected the existence of stochastic trends.

on the data generating process. The researcher will only assume that the recreated sample data contains all information in the distribution of the original sample of the population. In contrast, the Monte Carlo simulation applies not only the estimated parameters to forecast but also the model's covariance matrix. The parameter covariance matrix provides perturbations of the parameters for the forecasting process. In a system of equations the dynamic structure of the whole model is more important than that of any individual equation of the model. Two conditions can be assumed for a model which includes several equations and work as a system. Sometimes all equations may fit the model every well and be statistically significant, while the model as a system may not track the series of the data, which are being applied in the study, closely. In contrast, there may be some equations (in a system) which do not perform very well individually, but keeping them in the system will improve the ability of the model. A Monte Carlo ex post simulation is a useful technique that can make clear these kinds of situations. Then, according to the goal of investigation and overall statistical fit the researcher will decide whether the constructed specification is appropriate for that purpose. As indicated, there are some situations when researcher has to keep some equations in the system even if they are not preforming well, but improve the power of the model as a whole.

As previously indicated, the period being studied contains data from the first month of 1995 to April 2009. While the actual data for the period after April 2009 is also available, an ex post forecast which is an unconditional forecast has been generated. Then 95 percent confidence intervals for the model dependent variables are created. The confidence interval is a convenient statistical inference to test the reliability of the model performance by comparing the actual value of the dependent variable with forecasted values. If the actual value lies within the confidence intervals made by Monte Carlo forecasting method, one can conclude that the model being study is performed well. As indicated, Monte Carlo simulation is generating data by consideration of the estimated parameters and the perturbations of the parameters which are included in the model's covariance matrix. The results of the Monte Carlo simulation process, along with the actual values of the endogenous variables, are presented in the appendix III. Generally, the figures indicate that for most endogenous variables such as Chin's quantity component share in total expenditure, Ecuador's quantity component share in total expenditure, India's quantity component

share in total expenditure, Mexico's quantity component share in total expenditure, Other Countries quantity component share in total expenditure, and Gulf medium size shrimp's price component share in total expenditure, the simulated model fits very well, while in some other cases it does not. Another important result obtained from this method is that, for some countries, the actual and predicted values are fitting better since 2005 than earlier years before. In addition to the performance of Monte Carlo simulation, Theil's inequality measurements have also been provided. These statistical inferences are shown in next three tables.

Table 4.4. Descriptive Statistics for the Simultaneous Simulation, 2000 to 2011.

Variable[9]	N Obs	N	Actual		Predicted	
			Mean	Std Dev	Mean	Std Dev
WdC_PO	144	2.88E+05	-0.0008	0.024	-0.0012	0.023
WdE_PO	144	2.88E+05	0.0014	0.016	0.0022	0.023
WdIi_PO	144	2.88E+05	-0.0002	0.023	0.0004	0.022
WdIo_PO	144	2.88E+05	0.0015	0.019	0.0016	0.018
WdM_PO	144	2.88E+05	-0.0045	0.058	-0.0071	0.060
WdT_PO	144	2.88E+05	-0.0023	0.071	-0.0009	0.075
WdV_PO	144	2.88E+05	0.0012	0.033	0.0007	0.031
WdO_PO	144	2.88E+05	0.0022	0.038	0.0022	0.039
WdL1_PPP	144	2.88E+05	-0.0003	0.002	-0.0002	0.002
WdL2_PPP	144	2.88E+05	-0.0002	0.002	-0.0002	0.002

Table 4.4 illustrates the statistical description of the endogenous variables for actual and predicted value. In almost all cases, except for Ecuador's ordinary demand endogenous variable, the standard deviations of forecasts are very close to the actual standard deviations of the dependent variables.

Table 4.5. Statistics of Fit for the Simultaneous Simulation, 2000-2011.

Variable	N	Mean Error	Mean % Error	RMS Error	RMS % Error
WdC_PO	2.88E+05	-0.0003	-81.70	0.02	896.70
WdE_PO	2.88E+05	0.0008	180.80	0.02	6470.70
WdIi_PO	2.88E+05	0.0006	-186.40	0.02	2755.60

WdIo_PO	2.88E+05	0.0001	-42.32	0.02	781.60
WdM_PO	2.88E+05	-0.0026	-77.72	0.04	5221.80
WdT_PO	2.88E+05	0.0015	-27.32	0.05	2601.90
WdV_PO	2.88E+05	-0.0005	-96.98	0.03	2815.00
WdO_PO	2.88E+05	0.0000	242.20	0.04	4471.70
WdL1_PPP	2.88E+05	0.0001	-30.34	0.00	1413.10
WdL2_PPP	2.88E+05	0.0000	118.60	0.00	4370.50

In table 4.5 the mean simulation error, the mean percent error, root-mean-square (rms) simulation error, and RMS percent error are presented. These simulation statistics are quantitative instruments that measure whether historical simulation results match the behavior of the real world (endogenous variables) relatively closely. These criterions are defined as follows:

$$\text{Mean Simulation Error} = \frac{1}{T}\sum_{t=1}^{T}(Y_t^s - Y_t^a) \tag{4.6a}$$

$$\text{Mean Percent Error} = \frac{1}{T}\sum_{t=1}^{T}(\frac{Y_t^s - Y_t^a}{Y_t^a}) \tag{4.6b}$$

$$\text{Root Mean Square Error} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^s - Y_t^a)^2}$$

$$\tag{4.6c}$$

$$\text{RMS Percent Error} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(\frac{Y_t^s - Y_t^a}{Y_t^a})^2} \tag{4.6d}$$

where Y_t^s is the simulated value of endogenous variable, Y_t^a is the actual value of the endogenous variable, and T is the number of periods in the simulation. Mean simulation error calculates the mean of the difference between the predicted endogenous variable value and its true value. It is obvious that the smaller the MSE, the more perfect the prediction value, though this is not always the case. The mean square error may be equal or close to zero if the large positive errors cancel out the large negative errors. In statistical outcomes, along with the MSE measurement, the root mean square error is also reported. The RMS

eliminates the interaction of the positive and negative errors to each other. The RMS is the root square of MSE. Therefore, in some cases a RMS error is a more reliable measure of the simulation performance. However, the MSE is also useful, because it captures the systematic bias of the simulation performance, if the estimates are biased. As tables 4.5 illustrates both MSE and RMS error are small for all endogenous variables of the model.

The MSE and RMS error criterions are convenient for evaluating a historical simulation performance. There are some other criterions which are more beneficial for the ex post forecasts. These RMS forecast errors are evaluating the performance of the model by considering all endogenous variables forecast errors jointly in its formulation. These simulation statistics are presented in table 4.6.

Table 4.6. Theil Forecast Error Statistics for the Dynamic Simultaneous Simulation, 2000 to 2011.

MSE Decomposition Proportions								
			Corr	Bias	Var	Covar	Inequality Coef	
Variable	N	MSE	(R)	(UM)	(US)	(UC)	U1	U
WdC_PO	2.88E+05	0.0006	0.44	0.00	0.00	0.99	1.02	0.53
WdE_PO	2.88E+05	0.0006	0.25	0.00	0.07	0.93	1.51	0.62
WdIi_PO	2.88E+05	0.0005	0.48	0.00	0.00	1.00	0.99	0.51
WdIo_PO	2.88E+05	0.0005	0.28	0.00	0.00	1.00	1.15	0.60
WdM_PO	2.88E+05	0.0020	0.72	0.00	0.00	0.99	0.77	0.38
WdT_PO	2.88E+05	0.0025	0.77	0.00	0.01	0.99	0.71	0.34
WdV_PO	2.88E+05	0.0010	0.52	0.00	0.01	0.99	0.94	0.49
WdO_PO	2.88E+05	0.0018	0.40	0.00	0.00	1.00	1.13	0.55
WdL1_PPP	2.88E+05	0.0000	0.35	0.00	0.00	1.00	1.12	0.57
WdL2_PPP	2.88E+05	0.0000	0.33	0.00	0.02	0.98	1.24	0.58

The correlation error coefficient, Corr(R), represents the correlation between the actual values and forecast series:

$$\rho = \frac{cov(Y^s Y^a)}{\sigma_s \sigma_a}$$ (4.7)

where σ_s and σ_a refers to the standard deviations of the actual and forecast series of the data. Clearly, its value falls between zero and one. A value of zero or close to zero implies that the simulated series for the endogenous variables are imperfect representatives for the actual series. However, the value of 1 indicates a perfect match. Theil's inequality coefficient and its decomposed coefficients are defined as follows:

$$\text{Theil Inequality Coefficient:} \quad U = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^s)^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^a)^2}} \tag{4.8a}$$

$$\text{The Bias Proportion:} \quad U^M = \frac{(\bar{Y}^t - \bar{Y}^a)^2}{\frac{1}{T}\sum(Y_t^s - Y_t^a)^2} \tag{4.8b}$$

$$\text{The Variance Proportion:} \quad U^S = \frac{(\sigma_s - \sigma_a)^2}{\frac{1}{T}\sum(Y_t^s - Y_t^a)^2} \tag{4.8c}$$

$$\text{The Covariance Proportion:} \quad U^C = \frac{2(1-\rho)\sigma_s\sigma_a}{\frac{1}{T}\sum(Y_t^s - Y_t^a)^2}. \tag{4.8d}$$

Theil's inequality coefficient is bounded between zero and 1. The value of zero corresponds to the perfect performance of the model and the value of 1 indicates to perfect inequality or negative proportionality between actual and forecast value. The Theil decomposed proportions are allowing researchers for possible evaluation of the simulation error regarding its specific source. The sum of these three components equals 1. The bias proportion, U^M, represents the systematic error of the model. A value of zero or close to zero is implying to no or the least systematic bias, which is obviously preferred, regardless of the value of Theil's inequality coefficient (Pindyck and Rubinfeld, 1991). The variance proportion, U^S, implies how powerful the model is to repeat the degree of variability in the variable being studied. If the actual series of data contains considerable fluctuations while the forecasts series are not demonstrating these variations, the value of U^S will be large. In contrast, a small value of U^S indicates the simulated series (ex post forecast) captures the most variations/fluctuations of the actual value of the

series. The covariance component of the Theil's inequality refers to the unsystematic error. As indicated the sum of U^M, U^S, and U^C is 1. Consequently, the U^C is, in fact, the remaining error after the deviations from average values are taken into account.

As table 4.6 illustrates, the U^M and U^S values of all endogenous variables are representing a perfect performance of the Monte Carlo simulation (ex post forecast), although the correlation coefficients, Corr(R), indicate that the simulated values for some dependent variables are not fitting the actual value very well. The following simulation statistic is Theil's modified inequality coefficient which he introduced in 1966. The difference between the first one (U) and this criterion (U_1) is in their denominators. While the first simulation statistic, U, is bounded between zero and 1, the second one has only the lower bound, that is, the least value for U_1 is zero, but it has no upper bound value. Therefore, it is hard to decide which value implies the most prefect performance.

$$U_1 = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(Y_t^a)^2}} = \frac{\sqrt{\sum_{t=1}^{T}(Y_t^s - Y_t^a)^2}}{\sqrt{\sum_{t=1}^{T}(Y_t^a)^2}} . \tag{4.9}$$

4.3. Results and Interpretations

Prior to the interpretation of the results it is necessary to explain that a test for the homogeneity constrain, for each equation, has been conducted. The adding up and symmetry restrictions are not testable, while they are directly imposed in the model. The results of tests imply that the null hypotheses which are the homogeneity of degree zero respect to prices and income are statistically rejected in 97% level in favor of the alternative hypotheses, not being homogenous. These results are so common in deferential demand analysis. Ng in 1995, discuss that the reason that the homogeneity tests are rejected in most deferential demand system of equations studies, is incorporating of the non-stationary regressors. At this point, the only thing that the author is able to say is that this study's observations did not demonstrate a non-stationary

problem. As explained before, unit roots tests are demonstrated that this study's data have not unit roots. So, the cause of rejection of homogeneity tests might be some other unknown issues. It can be a subject of future studies.

In addition, a bootstrap resampling (with 1000 times repetitions) is also applied to confirm the validation of statistical inferences (t statistics). The residual bootstrap resampling demonstrates that all parameter estimates' "t statistics" are valid, and so all estimates are statistically significant. The significance of parameter estimates are shown in each section.

4.3.1. Model Parameter Estimates

The mixed Rotterdam demand system includes ten equations, after dropping one equation arbitrarily, due to preventing singularity condition for the contemporaneous error covariance matrix. U.S. shrimp imports are treated as a price-predetermined, or in other words, quantity dependent framework, and demand for Gulf shrimp is specified as a quantity-predetermined/price dependent framework. As mentioned earlier in chapter three, in the mixed demand approach, all equations of the system include both exogenous quantities and prices of the two groups of demand equations. In addition to these eleven explanatory variables, eleven dummy variables, a trend variable, and one more dummy variable for the year of 2005 to capture the effect of U.S. anti-dumping duties are added to the equations of the model. Consequently, every equation is composed of twenty four explanatory variables. The estimations of the basic parameters of the model and their approximate statistical summary are presented in table 4.7.

This table includes the model's marginal budget share parameter estimates, θ_i and γ_r, and the reciprocal of the income elasticity of the marginal utility of income parameter estimate, ϕ. The marginal budget share (or marginal share) coefficients refer to the amount of money that an individual will spend on good i, if his/her income rises by one dollar (Theil, 1987).

As table 4.7 shows, all marginal shares estimated coefficients' signs are consistent with consumer demand theory, as explained in the previous chapter. The inverse of the income elasticity of the marginal utility of income parameter estimate also has the negative sign consistent with theory. All these parameter

estimates are also statistically significant at a 1% level, approximately, except for the small size Gulf shrimp product which is statistically significant at a 5% level. The imports demand equations' dependent variables demonstrate the quantity components of the change in the budget share, while the Gulf landings dependent variables comprise the price components of the change in the budget share.

Table 4.7. Parameter Estimates, Their Approximate
Standard Deviation, and t-Statistic, 1995(1)-2010(4).

Parameter	Estimate	Approx Std Err	t Value	Approx Pr > |t|
cc (ϕ)	-0.2916	0.0477	-6.12	<.0001
c1 (θ_C)	0.0683	0.0112	6.09	<.0001
c2 (θ_E)	0.0356	0.0131	2.71	0.0075
c3 (θ_{Ii})	0.0933	0.0109	8.53	<.0001
c4 (θ_{Io})	0.0327	0.0103	3.18	0.0018
c5 (θ_M)	0.1277	0.0210	6.07	<.0001
c6 (θ_T)	0.4025	0.0249	16.19	<.0001
c7 (θ_V)	0.1198	0.0138	8.70	<.0001
c8 (θ_V)	0.1047	0.0200	5.24	<.0001
s1 ($-\gamma_{L1}$)	-0.0044	0.0009	-4.68	<.0001
s2 ($-\gamma_{L2}$)	-0.0044	0.0011	-4.01	<.0001
s3 ($-\gamma_{L3}$)	-0.0063	0.0032	-1.96	0.0511

The interpretation of the coefficient estimates are presented as Theil's study (1987). The China's demand equation coefficient estimates, for the marginal share, indicates that if U.S. expenditures on shrimp products increases by $100 this country will spend $7 more to import shrimp products from China, considering all other variables are fixed.

The same interpretation is applicable for the marginal budget share coefficients of all other countries. For example, the U.S. will spend $40 on shrimp imports from Thailand, with all other variables constant, if its total expenditure on shrimp products increases by100$, which is the highest marginal share among all countries. Mexico's coefficient estimates for the marginal budget share is the second highest,

after Thailand. If the U.S. expenditure on shrimp products increases by 100 dollars with all other variables constant, this country will spend $12 of it on importing shrimps from Mexico (figure 4.1).
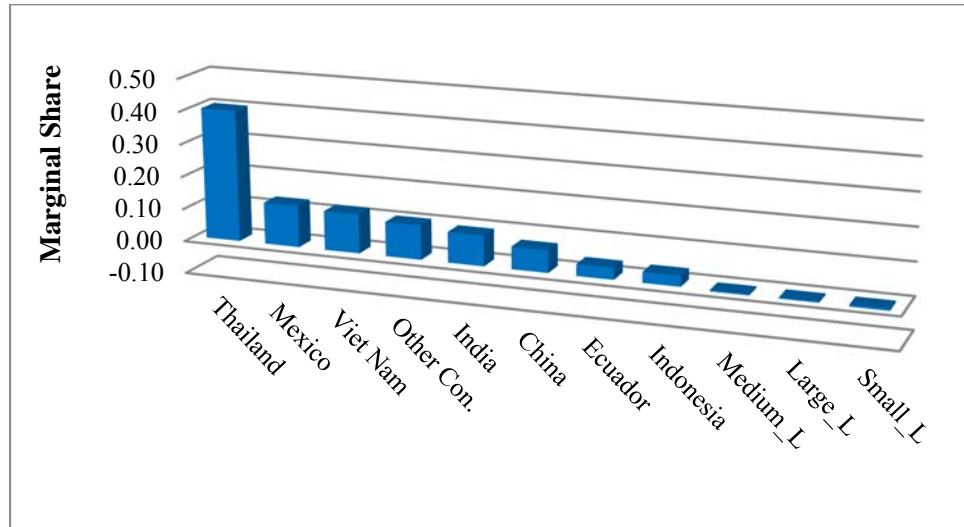
Figure 4.1. Marginal Budget Share Estimates by Each Country and Gulf Landings, 1995(1)-2010(4).

It is important to explain that, as it is shown in table 4.7, the Gulf landings marginal share coefficients are negative. These negative signs are representing the negative of minus marginal budget shares, which are, in turn, expressing positive signs of the marginal budget shares for the Gulf landings. Accordingly, the Gulf shrimp landings marginal share coefficients can be interpreted similar to these coefficients for the U.S. shrimp imports. For example, the U.S. is willing to spend 44 cent on Gulf large are summarized in table 4.8. As the table demonstrates, the anti-dumping dummy parameter estimates are only significant for Ecuador, India, size shrimp products if its total expenditure on the shrimp products increases by 100 dollars, considering all other variables are fixed.

4.3.2. Anti-dumping Parameter Estimates

Anti-dumping duties imposed on six countries including China, Ecuador, India, Thailand, Vietnam, and Brazil in 2005. All these countries except Brazil are included in this study. Therefore, an anti-dumping dummy variable can be used to examine the effects of this policy on the U.S. shrimp market. The results

Mexico, and all Other Countries export (to the U.S.) variables. Ecuador's and Mexico's coefficient estimates are statistically significant at 1% level, while the coefficients for India and Other Countries' exports to the U.S. are statistically significant at 10% and 5% levels, respectively. The antidumping estimates are negative for Ecuador, India, and Other countries, though it is positive for Mexico. That is, antidumping duties have had a negative effect on Ecuador and India exports to the United States. As expected, these duties have had positive effects on Mexico, which is not subject to anti-dumping resolutions. In other words, the antidumping duties caused Ecuador and India's exports to decrease, but Mexico's exports to rise. Ecuador and India quantity shares of U.S. expenditures on shrimp have been declined by 0.01 and 0.01 for every level of price, since the last quarter of 2004 (months October, November, and December), respectively. Note that in this study, the anti-dumping effect captures indirectly through market price adjustment, as anti-dumping duties only affect the supply of shrimp imports.

Table 4.8. Antidumping Parameter Estimates, Their Approximate Standard Deviations, and t-Statistics, 1995(1)-2010(4).

Anti-Dumping Parameter Estimates	Estimate	Approx Std Err	t Value	Approx Pr > |t|
d_China	-0.0019	0.0038	-0.51	0.6109
d_Ecuador	-0.0095	0.0040	-2.40	0.0175
d_India	-0.0058	0.0034	-1.70	0.0914
d_Indonesia	-0.0036	0.0033	-1.09	0.2765
d_Mexico	0.0231	0.0069	3.34	0.0010
d_Thailand	0.0119	0.0078	1.54	0.1256
d_Vietnam	-0.0016	0.0047	-0.33	0.7404
d_Other Countries	-0.0121	0.0062	-1.94	0.0546
d_Large Shrimps	-0.0005	0.0005	-1.16	0.2459
d_Med Shrimps	-0.0005	0.0004	-1.11	0.2699
d_Small Shrimps	0.0006	0.0014	0.43	0.6695

In general, as theoretically expected, the anti-dumping duties (on those six named countries in the law) should reduce their exports to the Unites States. Therefore, the supply of shrimp imports from these countries will shift to the left. Consequently, the market equilibrium will change, as the demand function is stable. That is, at a new equilibrium point, the quantity of demand will decrease. Therefore, the indicated parameter estimates are demonstrating the demand quantities at new market equilibrium.

In contrast, antidumping duties motivate Mexico's quantity share of U.S. total expenditures on shrimp to increase by 0.02 in every level of price after October 2004.

4.3.3. Monthly Dummy Parameter Estimates

As indicated, the data for Gulf shrimp landings and shrimp imports display considerable seasonal variability. Given the assumption that the seasonal variations may not be captured with the price changes, the monthly dummy variables are added to the equations of the model. In fact, monthly dummy variables are included to grab the effect of a number of unmeasured time related elements. Like the antidumping dummy variable, these dummy variables are also regarded as shift variables for the supply of Gulf shrimp. There are eleven monthly dummy variables in every equation. The last month's dummy variable has been dropped in each equation to avoid the full collinearity problem.

Accordingly, any dummy variable that appears in the system is being compared with the last month, December. The estimated results and their asymptotic standard errors are given in table 4.9. For the China's regular demand equation; only March, April, and November dummy variables are significant. The monthly dummy coefficient of March is negative which means that China's share in U.S. total expenditure on shrimp productions in the month of March is %2.1 less than December. Both monthly dummy coefficient estimates of April and November are positive which mean that China's share in U.S. total expenditure on shrimps in months April and November are %1.0 and %1.1 less than December, respectively. Ecuador' monthly dummy coefficient estimates for the months of February and April are not significant.

Table 4.9. Parameter Estimates for Monthly Dummy Variables, 1995(1)-2010(4).

		Jan. Dummy	Feb. Dummy	Mar. Dummy	Apr. Dummy	May Dummy	Jun. Dummy	Jul. Dummy	Aug. Dummy	Sep. Dummy	Oct. Dummy	Nov. Dummy
China	**Estimate**	0.004	-0.005	-0.021*	0.010***	0.004	-0.009	0.007	0.004	0.004	-0.006	0.011**
	Std Err	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
	t Value	0.75	-0.99	-3.81	1.81	0.75	-1.39	1.13	0.73	0.66	-0.92	1.96
Ecuador	**Estimate**	-0.012**	-0.004	0.012**	-0.009	-0.017*	-0.019*	-0.028*	-0.029*	-0.028*	-0.019*	-0.020*
	Std Err	0.007	0.006	0.006	0.006	0.006	0.007	0.007	0.007	0.007	0.007	0.006
	t Value	-1.83	-0.65	1.93	-1.48	-2.69	-2.73	-4.20	-4.32	-4.27	-2.77	-3.17
India	**Estimate**	0.011**	-0.006	-0.008	-0.021*	-0.016*	-0.019*	-0.001	-0.003	-0.024*	-0.031*	-0.011**
	Std Err	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006	0.005
	t Value	2.10	-1.24	-1.56	-4.05	-3.14	-3.30	-0.25	-0.51	-4.24	-5.28	-2.11
Indonesia	**Estimate**	0.005	0.002	0.016*	-0.014*	0.003	-0.009	-0.005	-0.002	-0.013*	-0.008	0.009***
	Std Err	0.005	0.005	0.005	0.005	0.005	0.006	0.005	0.005	0.005	0.006	0.005
	t Value	1.01	0.37	3.29	-2.83	0.65	-1.64	-0.88	-0.41	-2.50	-1.34	-1.84
Mexico	**Estimate**	0.004	0.018***	0.026*	0.023**	0.009	0.002	0.021***	0.038*	0.108*	0.128*	-0.001
	Std Err	0.011	0.010	0.010	0.010	0.011	0.012	0.012	0.011	0.011	0.011	0.011
	t Value	0.37	1.78	2.49	2.21	0.83	0.16	1.79	3.35	10.06	11.16	-0.11
Thailand	**Estimate**	-0.007	0.012	-0.004	0.003	-0.007	0.021	-0.008	0.004	-0.003	-0.011	0.044*
	Std Err	0.012	0.011	0.011	0.012	0.012	0.013	0.013	0.013	0.012	0.013	0.012
	t Value	-0.54	1.09	-0.37	0.26	-0.60	1.64	-0.65	0.31	-0.28	-0.82	3.67
Vietnam	**Estimate**	0.017*	-0.003	-0.005	0.003	0.008	0.011	-0.003	0.005	-0.003	0.014***	0.002
	Std Err	0.007	0.007	0.007	0.007	0.007	0.008	0.008	0.008	0.007	0.008	0.007
	t Value	2.38	-0.43	-0.68	0.45	1.18	1.48	-0.35	0.66	-0.38	-1.86	0.31
Other Count.	**Estimate**	-0.023**	0.016***	0.015***	0.005	0.033*	0.004	0.012	-0.012	-0.033*	-0.037*	-0.015
	Std Err	0.010	0.009	0.009	0.009	0.009	0.011	0.010	0.010	0.010	0.010	0.010
	t Value	-2.320	-1.740	-1.660	0.500	3.540	0.390	1.210	-1.200	-3.360	-3.610	-1.600
Large Size Landings	**Estimate**	-0.001	0.001*	0.000	0.000	-0.001	-0.001*	-0.001	-0.004*	-0.004*	-0.001**	0.000
	Std Err	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	t Value	-1.20	2.38	-0.83	-0.09	-1.07	-2.49	-1.02	-6.94	-6.14	-2.35	0.53
Medium Size Landings	**Estimate**	0.000	0.000	-0.001	0.000	-0.001	-0.001**	-0.004	-0.001	0.000	-0.001	0.000
	Std Err	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	t Value	0.18	0.34	-0.92	-0.13	-0.86	-2.03	-6.42	-1.45	-0.68	-1.18	-0.65
Small Size Landings	**Estimate**	0.001	0.001	0.002	0.000	-0.017*	0.020*	0.010*	0.000	-0.004***	0.000	0.000
	Std Err	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.002	0.002	0.002
	t Value	0.40	0.58	0.85	0.17	-5.63	9.98	4.62	0.12	-1.80	0.15	0.21

*significant at 1% level
**significant at 5% level
***significant at 10% level
Without * means is not significant

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In all other months the monthly dummy parameter estimates make a shift in the demand equation of Ecuador's imports to the U.S. with respect to month December. In months January, April, May, September, October, and November, monthly dummy parameter estimates are making a shift in the demand equation in regard to December. While in January, India's share in imports to the U.S. is %1.1 more than December. In months April, May, June, September, October, and November with respect to the month of December India's share in U.S. total expenditure on shrimp products declines. In contrast, Mexico's shares in the U.S. total expenditure on shrimps are higher than December in most months.

As demonstrated in table 4.9, most of the monthly dummy coefficient estimates are not statistically significant. The main reason for including monthly dummy variables in the system is to avoid specification error. The primary interest of this study is to estimate the determinants of the U.S demand for the shrimp products. Eliminating the seasonal variations from the model could result in a misspecified model, which in turn may cause the coefficient estimates to be biased. In this regard, either the significance of coefficient estimates or testing hypothesis about these estimates are not of particular interest.

4.3.4. Trend Parameter Estimates

As indicated, some upward time trends have been identified in the imports data, as is common in time series observations. Ignoring this data tendency may lead to misconclusion of variable responsiveness, especially when serial correlation is an issue[10].

As table 4.10 illustrates, the trend parameter estimates for Ecuador, India, Mexico, Other Countries, and Large size Gulf shrimp productions are significant, although their estimates are negligible. The important issue is that detrending the data has been assisted to a major reduction of autocorrelation problem in the error covariance matrix.

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[10] As explained, observations which are incorporated in this study have no unit roots problem. So, only deterministic trends are under consideration.

Table 4.10. Trend Parameter Estimates, Their Approximate
Standard Deviation, and t-Statistic, 1995(1)-2010(4).

Trend Parameter Estimates	Estimate	Approx Std Err	t Value	Approx Pr > |t|
t_China	0.00000	0.00003	-0.05	0.9595
t_Ecuador	0.00011	0.00003	3.69	0.0003
t_India	0.00007	0.00003	2.87	0.0046
t_Indonesia	0.00003	0.00002	1.36	0.1765
t_Mexico	-0.00025	0.00005	-4.99	<.0001
t_Thailand	-0.00005	0.00006	-0.94	0.3509
t_Vietnam	0.00000	0.00003	0.01	0.9948
t_Other Countries	0.00009	0.00005	1.92	0.0566
t_Large Size Shrimp	0.00001	0.00000	1.79	0.0750
t_Medium Size Shrimp	0.00000	0.00000	1.35	0.1777
t_Small Size Shrimp	-0.00001	0.00001	-0.51	0.6096

4.3.5. Elasticity Estimates

Estimated elasticities will provide a better understanding of a mixed Rotterdam demand equations. As indicated, the Rotterdam specification has been defined under double-log functions, this property makes the estimation of the demand elasticity terms straightforward. These elasticities are uncompensated elasticities (Brown and Lee, 2006). While the dependent variables are the budget shares times log differences, these elasticities are calculated at mean point of budget shares.

In this study the mixed Rotterdam demand system includes eleven equations. Every equation comprises eleven price and quantity explanatory variables that associate with elasticity measurements. Therefore, this demand model contains 143 elasticity estimates. This mixed Rotterdam demand system is accomplished with eight regular demand equations and three inverse demand equations. Accordingly, some of these elasticity estimates are reflecting the flexibility estimates, but in a mixed demand specification all of them are considered as elasticity to be convenient to interpret. As indicated in the previous chapter, all these elasticity estimates are uncompensated demand elasticities due to consideration of Marshaillan (ordinary) demands in this mixed Rotterdam specification.

4.3.5.1. Uncompensated Price Elasticity of Ordinary Demand

Table 4.11 illustrates the uncompensated price elasticity estimates which are obtained from ordinary demand functions (imports demand equations). In this table, along with the price elasticity estimates their standard deviation and t-value statistics are presented. As it is shown in table 4.11, all own price elasticities (diagonal elements) are negative and cross-price elasticities are positive. The cross-price elasticity of demand measures the interdependence of the different products or different types of one product. The positive cross-price elasticities mean the imported shrimps from all countries are a substitute for one another. For example, if the ratio of India's monthly shrimp export price increases by 1%, the ratio of consumption for China's shrimp will increase by 0.04% (row 1, column 3), holding all other variables constant.

The magnitudes of all elasticities are less than 1%, because they are the ratio lagged monthly price[11]. Consequently, it cannot be concluded that whether the demand functions are elastic or inelastic. The element of row 8, column 1 indicates that if the ratio of China's price of shrimp exports increases by 1%, the ratio of consumption for U.S. shrimp imports from all Other Countries, which are not included to the model directly, will only increase by 0.01%, while all other factors are fixed. As indicated, the own-price elasticities of demand for all countries which are included into the model are negative. It shows the percentage of decreases in the ratio of consumption if the ratio of prices from one month to a month before increases by one percent. The negative signs imply that a one percent increase in ratio of price for example for India (column 3, row 3) will cause the ratio of quantity of demand for India to decrease by 0.43%, holding all other variables constant. Own-price elasticity of Thailand imports demand to the U.S. is (-0.25) indicating that an increase in the ratio of shrimp imports price of Thailand by 1% will cause the ratio of quantity of demand for this country to fall by 0.25%, holding all other factors constant. The largest ratio of effect belongs to India and Vietnam, which is about (-0.43%) for both countries.

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[11] Uncompensated elasticities are elasticity estimates of the Marshallian/ordinary demand curve in which the consumer's income is holding constant. An alternative demand curve is the Hicksian/compensated demand function, in which the consumer's utility will hold constant. Compensated elasticities are the elasticity estimates of these types of demand curves.

This means if the India and Vietnam price of imports go up by 1%, the quantity of demand for each of these countries will decline by 0.43%, with all other factors being fixed. The second largest own-price elasticity of demand goes to China and Mexico which is about (-0.40%). As table 4.11 demonstrates, the own-price elasticity of demand for Thailand (-0.25%) is less than China, India, Mexico, and Vietnam.

A glance at the table 4.11 indicates that Thailand has the largest cross-price elasticity of demand (column 6) among all exporting countries. For example, the effect of a 1% increase in Thailand shrimp export prices on China's shrimp export quantities to the U.S. is an increase of 0.17%. This estimate for Ecuador, India, Indonesia, Mexico, Vietnam, and Other Countries is an increase of 0.04%, 0.19%, 0.05%, 0.19%, 0.19%, and 0.7%, respectively.

Several factors can influence the price elasticity of demand. The number of substitutes and the extent to which the substitute goods are available are important factors. Other factors include the amount of income one allocates to the good, the type of good, and time to adjust. For instance, if the price of a good goes up while the consumer's income stays the same, he or she will buy less of that good. Therefore, a good's demand is more sensitive to change in price if there is no change in the consumer's income. The type of commodity is also important. For example, even a large increase in price does not drastically decrease consumption of a necessary good. A consumer can find a better substitute for a good if he or she has enough time to search for an acceptable substitution. The only factor among all these factors that makes a difference between Thailand and named countries above is the number of substitutions for the Thailand's shrimp. It seems Thailand's shrimp is strong substitutes for China, India, Mexico, and Vietnam's shrimp products. However, the reverse relationship is not true. Other factors such as time and income have the same effect on these countries, while in this study, the demand market and duration of research are the same for all these countries.

Table 4.11. Uncompensated Price Elasticity Estimates for Ordinary Demand, 1995(1)-2010(4).

		China	Ecuador	India	Indonesia	Mexico	Thailand	Vietnam	Other Countries
China	**Estimate**	-0.399*	0.015**	0.040*	0.014*	0.055*	0.172*	0.051*	0.045*
	Std Err	0.083	0.006	0.010	0.005	0.014	0.038	0.013	0.012
	t Value	-4.82	2.35	4.08	2.83	3.97	4.50	3.95	3.73
Ecuador	**Estimate**	0.007**	-0.103*	0.010**	0.003**	0.014**	0.043*	0.013*	0.011**
	Std Err	0.003	0.040	0.004	0.002	0.006	0.017	0.005	0.005
	t Value	2.35	-2.55	2.43	2.20	2.38	2.49	2.51	2.25
India	**Estimate**	0.032*	0.017**	-0.429*	0.016*	0.060*	0.191*	0.057*	0.050*
	Std Err	0.008	0.007	0.082	0.006	0.015	0.040	0.013	0.013
	t Value	4.08	2.43	-5.22	2.69	4.05	4.77	4.51	3.78
Indonesia	**Estimate**	0.009*	0.005**	0.012*	-0.128*	0.017*	0.053*	0.016*	0.014**
	Std Err	0.003	0.002	0.005	0.045	0.007	0.019	0.006	0.006
	t Value	2.83	2.20	2.69	-2.87	2.56	2.77	2.82	2.41
Mexico	**Estimate**	0.031*	0.016**	0.043*	0.015*	-0.401*	0.185*	0.055*	0.048*
	Std Err	0.008	0.007	0.011	0.006	0.089	0.044	0.013	0.014
	t Value	3.97	2.38	4.05	2.56	-4.51	4.19	4.10	3.44
Thailand	**Estimate**	0.028*	0.015*	0.038*	0.013*	0.052*	-0.246*	0.049*	0.043*
	Std Err	0.006	0.006	0.008	0.005	0.013	0.041	0.010	0.011
	t Value	4.50	2.49	4.77	2.77	4.19	-5.99	5.11	4.08
Vietnam	**Estimate**	0.033*	0.017*	0.045*	0.016*	0.062*	0.194*	-0.425*	0.051*
	Std Err	0.008	0.007	0.010	0.006	0.015	0.038	0.077	0.013
	t Value	3.95	2.51	4.51	2.82	4.10	5.11	-5.52	3.92
Other Countires	**Estimate**	0.011*	0.006*	0.015*	0.005*	0.021*	0.066*	0.020*	-0.146*
	Std Err	0.003	0.003	0.004	0.002	0.006	0.016	0.005	0.035
	t Value	3.73	2.25	3.78	2.41	3.44	4.08	3.92	-4.23

*significant at 1% level

**significant at 5% level

***significant at 10% level

Without * means is not significant

The Lerner index demonstrates the relationship between a firm's price elasticity of demand and its market power. Relationship between marginal revenue and elasticity:

$$MR = P(1 + \frac{1}{\varepsilon_{px,X}}) \qquad (4.10a)$$

$$MR = MC \qquad (4.10b)$$

$$MC = p(1 + \frac{1}{\varepsilon_{px,X}}) \qquad (4.10c)$$

$$MC = (P + \frac{P}{\varepsilon_{px,X}}) \qquad (4.10d)$$

$$P - MC = -\frac{P}{\varepsilon_{px,X}} \qquad (4.10e)$$

$$\frac{P - MC}{P} = -\frac{P}{\varepsilon_{px,X}} * \frac{1}{P} \qquad (4.10f)$$

$$-\frac{1}{\varepsilon_{px,X}} = \frac{P - MC}{P} \qquad (4.10g)$$

Lerner Index: $\quad -\frac{1}{\varepsilon_{px,X}} = \frac{P - MC}{P} = L$. $\qquad (4.10h)$

This index along with Thailand's largest share in U.S. total expenditures on shrimp reveals that Thailand has some degree of market power relative to China, India, Mexico, and Vietnam in the U.S. shrimp industry.

4.3.5.2. Uncompensated Price Elasticity of Inverse Demand

In this section the estimation of uncompensated price elasticities for the Gulf shrimp landings are presented. Figure 4.2 and table 4.12 demonstrates these estimations. The price elasticity of these inverse demand equations are determined by the ratio of Gulf dockside price change from one month to a month before, resulting from a one percent change in the ratio of price, from one month to a month before, for a selected country.

Table 4.12. Uncompensated Price Flexibility/Elasticity Estimates for the Inverse Demand, 1995(1)-2010(4).

		China	Ecuador	India	Indonesia	Mexico	Thailand	Vietnam	Other Countries
Large	**Estimate**	0.002*	0.001**	0.003*	0.001*	0.005*	0.014*	0.004*	0.004*
Size	**Std Err**	0.001	0.001	0.001	0.000	0.001	0.003	0.001	0.001
Landings	**t Value**	3.73	2.26	4.03	2.49	3.72	4.24	4.15	3.34
Medium	**Estimate**	0.003*	0.002**	0.004*	0.001*	0.006*	0.018*	0.005*	0.005*
Size	**Std Err**	0.001	0.001	0.001	0.001	0.002	0.005	0.001	0.002
Landings	**t Value**	3.41	2.15	3.72	2.58	3.27	3.84	3.84	3.09
Small	**Estimate**	0.004**	0.002***	0.005**	0.002***	0.007**	0.022**	0.006**	0.006**
Size	**Std Err**	0.002	0.001	0.002	0.001	0.004	0.011	0.003	0.003
Landings	**t Value**	1.95	1.65	2.08	1.72	1.98	2.06	2.05	1.93

*significant at 1% level

**significant at 5% level

***significant at 10% level

Without * means is not significant

As table 4.12 demonstrates, all elasticity estimates are positive and statistically significant at 1% and 5% levels, which implies that if a county's ratio of price changes by 1%, the ratio of Gulf shrimp landings for any selected size will also increase. This relation seems rational. That is, an increase in the ratio of export price of a country will cause the consumption for this country's shrimp productions to decrease. At a fixed supply, the demand for the Gulf shrimps will shift to the right, indicating that in every level of quantity demanded, the price of Gulf shrimp also increases.
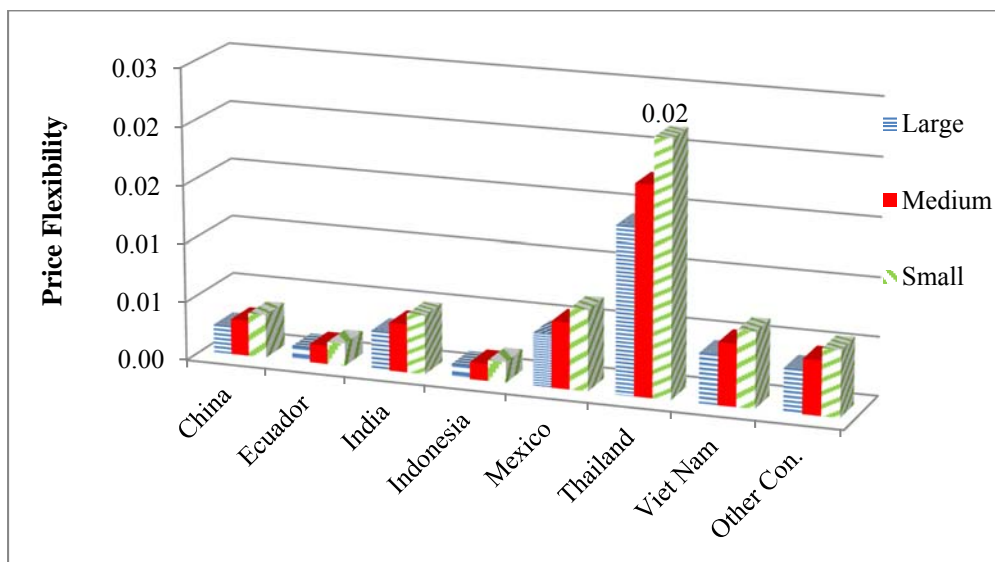
Figure 4.2. Price Flexibility of Inverse Demand, 1995(1)-2010(4).

The most effective price changes on Gulf landings associated with Thailand's shrimp export prices. A one percent increase in the ratio of Thailand shrimp prices will increase the price of large, medium, and small sizes of Gulf shrimp products by 0.01%, 0.02%, and 0.02%, respectively.

4.3.5.3. Uncompensated Quantity Elasticity of Ordinary Demand

These elasticity estimates are demonstrated in table 4.13; they are estimated from the imports demand equations, as they are regular (or ordinary) demand equations in the system. They show the quantity-quantity responsiveness between the Gulf shrimp quantity of landings and the quantity of shrimp imports to the U.S. from countries which are included in this study.

As table 4.13 illustrates, all the elasticity estimates are positive, as is theoretically expected and all of them are statistically significant. It is important to say that, in this process, a change in the Gulf shrimp products has an indirect effect on the quantity of shrimp imports. For example, the quantity elasticity estimated for the Gulf large size shrimps equals 0.002, implying a 1% increase in the ratio of quantity of demand for the Gulf large shrimp (from one month to a month before) increases the ratio of consumption for the shrimp imports from China by 0.002%, all other factors are held constant.

Table 4.13. Uncompensated Quantity Elasticity Estimates for the Ordinary Demand, 1995(1)-2010(4).

		Large Size Landings	Medium Size Landings	Small Size Landings
China	**Estimate**	0.002*	0.002*	0.003**
	Std Err	0.001	0.001	0.001
	t Value	3.73	3.41	1.95
Ecuador	**Estimate**	0.001**	0.001**	0.001***
	Std Err	0.0002	0.0002	0.0004
	t Value	2.26	2.15	1.65
India	**Estimate**	0.002*	0.002*	0.003**
	Std Err	0.001	0.001	0.002
	t Value	4.03	3.72	2.08
Indonesia	**Estimate**	0.001*	0.001*	0.001***
	Std Err	0.000	0.000	0.001
	t Value	2.49	2.58	1.72
Mexico	**Estimate**	0.002*	0.002*	0.003**
	Std Err	0.0005	0.0006	0.0016
	t Value	3.72	3.27	1.98
Thailand	**Estimate**	0.002*	0.002*	0.003**
	Std Err	0.000	0.000	0.001
	t Value	4.24	3.84	2.06
Vietnam	**Estimate**	0.002*	0.002*	0.003**
	Std Err	0.001	0.001	0.002
	t Value	4.15	3.84	2.05
Other Countries	**Estimate**	0.001*	0.001*	0.001**
	Std Err	0.000	0.000	0.001
	t Value	3.34	3.09	1.93

*significant at 1% level
**significant at 5% level
***significant at 10% level
Without * means is not significant

All other elasticity estimates which are shown in this table can be interpreted in the same way. As table 4.13 illustrates, all the effects are very small.

4.3.5.4. Uncompensated Quantity Elasticity of Inverse Demand

The quantity elasticities/flexibility estimations express the percentage changes in value of the ratio of Gulf dockside prices regarding the 1% change in the ratio of Gulf shrimp landings' quantities. In fact, these elasticities indicate the interrelations between the Gulf large, medium, and small size shrimps prices and quantities (table 4.14).

Table 4.14. Uncompensated Quantity Flexibility/Elasticity Estimates for the
Inverse Demand, 1995(1)-2010(4).

		Large Size Landings	Medium Size Landings	Small Size Landings
Large Size Landings	**Estimate**	-0.0352	0.0002	0.0002
	Std Err	0.008	0.000	0.000
	t Value	-4.47	2.68	1.91
Medium Size Landings	**Estimate**	0.0002	-0.0441	0.0003
	Std Err	0.000	0.011	0.000
	t Value	2.68	-3.98	1.81
Small Size Landings	**Estimate**	0.0002	0.0002	-0.0538
	Std Err	0.000	0.000	0.026
	t Value	1.91	1.81	-2.09

*significant at 1% level

**significant at 5% level

***significant at 10% level

Without * means is not significant

As theoretically expected, the own-quantity elasticities of inverse demand are negative and cross-quantity elasticities of inverse demand are positive. If the ratio of Gulf large shrimp landings, from one month to a month before, goes up by 1% the ratio of Gulf large size shrimp dockside price decreases by 0.035%, with all other variables are constant. If the ratio of Gulf medium size shrimp landings from one month to a month before increases by 1%, the ratio of Gulf medium size shrimp dockside price decreases by 0.044%, while all other factors are constant. If the ratio of Gulf small size shrimp landings from one

month to a month before goes up by 1%, the ratio of Gulf small size shrimp dockside price will decrease by 0.054%, holding all other factors constant. A one percent increase in the ratio of large size shrimp landings will cause the ratio of medium and small size Gulf shrimp dockside price to go up by 0.0002% and 0.0002%, respectively, holding all other variables constant. If the ratio of consumption for the medium size of Gulf shrimp goes up by 1%, the ratio of Gulf shrimp dockside prices for the large and small sizes will increase by 0.0002% and 0.0002%, respectively, while all other variables are fixed.

4.3.5.5. Income/Expenditure Elasticity of Ordinary Demand

The calculation of income elasticities for the regular demand equations of the system are presented in the previous chapter,

$$\eta_{ai} = \frac{\theta_i}{w_{ai}}. \tag{4.11}$$

These elasticities are estimated at the mean value of budget share. As indicated, these elasticities attributed to the relations between the U.S. income/ expenditure on shrimp products and the quantity of imports for every country, as they are the endogenous variables for the regular demand equations. Table 4.15 presents these estimations. As shown in table 4.15, all income elasticity estimates for ordinary demand are positive. That is, if the American expenditure on shrimp products increases by 1%, they will spend some of this increase on shrimp imports. For example, the income elasticity of demand coefficient for China is 1.46, implying that if the American expenditure on shrimp products increases by 1%, their consumption of China's shrimp will increase by 1.46%. Since this coefficient estimate is more than one, it means that if the American expenditure on shrimp products increases, the share of China's shrimp quantity (consumed by American) will also increase. Americans will not only buy more China's shrimp but they will also substitute other countries shrimp products for China's shrimp product. This means that China's share in total expenditure will also increase. These coefficient estimates for India, Mexico, Thailand, and Vietnam are more than one and equal 1.62, 1.58, 1.41, and 1.66, respectively. These coefficient estimates for Ecuador, Indonesia, and Other Countries are less than one, and equal 0.36, 0.46, and 0.56, respectively. This means that if the American expenditure on shrimp products increases by 1%, they will increase their consumption

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of these countries shrimp products by 0.37%, 0.46%, and 0.56%, respectively. Because these estimates are less than one, it means these countries' shares will decrease. As indicated, the income elasticity contains not only the proportionate change resulting from a scale expansion in the consumption bundle, but also the elasticity of substitution effects (Park and Thurman, 1999). So, if it equals one, it means the consumer will not change the proportion of consuming that good. The share of the good is held the same as before, which shows that preferences are homothetic. When it is less than one for some goods, it means when income/expenditure increases, the consumer will increase his/her consumption of those commodities but the goods' proportions, related to other goods, will decrease. In our case, Americans substitute some of their consumption of Ecuador, Indonesia, and Other Countries shrimp products for other countries shrimps, such as Mexico or China. Some other justifications about the income elasticities of demand related to the type of commodity.
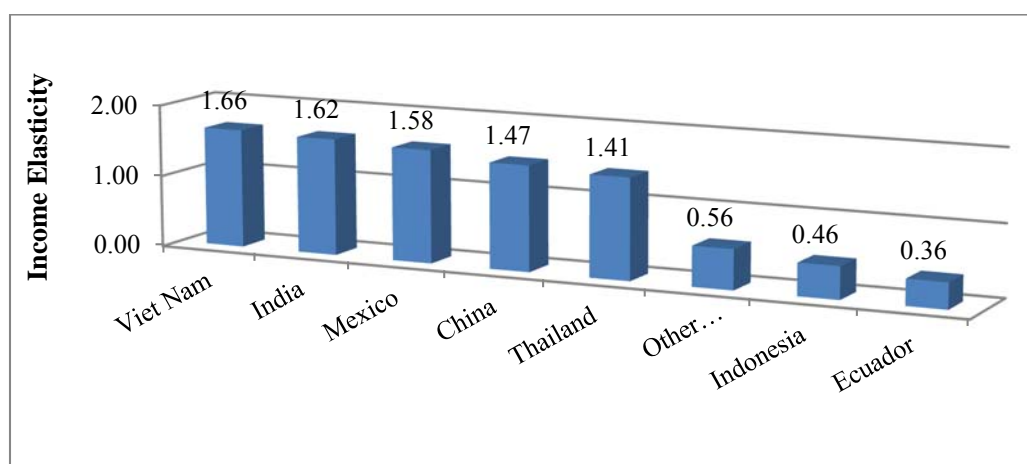
Figure 4.3. Income Elasticity of Ordinary Demand, 1995(1)-2010(4).

If the income elasticity of demand is negative, it is interpreted as inferior goods. As income elasticity is positive, but less than one, the commodity will fall into the normal goods category. Finally, income elasticity greater than one refers to luxuries. In this regard, all countries shrimp products except Ecuador, Indonesia, and Other Countries may be considered luxuries. For Ecuador, Indonesia, and all Other Countries' not named in this study directly, imported shrimp products are taken as normal goods.

Table 4.15. Income Elasticity Estimates for Ordinary Demand, 1995(1)-2010(4).

	China	Ecuador	India	Indonesia	Mexico	Thailand	Vietnam	Other Countries
Estimate	1.468*	0.365*	1.624*	0.455*	1.576*	1.409*	1.657*	0.561*
Std Err	0.241	0.135	0.190	0.143	0.260	0.087	0.190	0.107
t Value	6.09	2.71	8.53	3.18	6.07	16.19	8.7	5.24

*significant at 1% level
**significant at 5% level
***significant at 10% level
Without * means is not significant

4.3.5.6. Income/Expenditure Elasticity of Inverse Demand

The income elasticities of inverse demand equations of the system are the ratio of marginal budget share of a commodity to its corresponding budget share

$$\eta_{br} = \frac{-\gamma_r}{w_{br}} .$$
(4.12)

Like income elasticity of regular demand, the income elasticities for inverse demand equations are also estimated at mean value of budget shares. The income/expenditure elasticity of inverse demand is associated with the responsiveness between the American income/expenditure and the Gulf dockside prices.

As indicated, the income elasticity illustrates the effect of income on endogenous variables. For the inverse demand equations in mixed model the Gulf shrimp prices are endogenous variables. That is, for example, if the American expenditure on shrimp products increases by 1%, they will spend 0.12%, 0.12%, and 0.19% of that on the Large, Medium, and Small size shrimps, respectively.
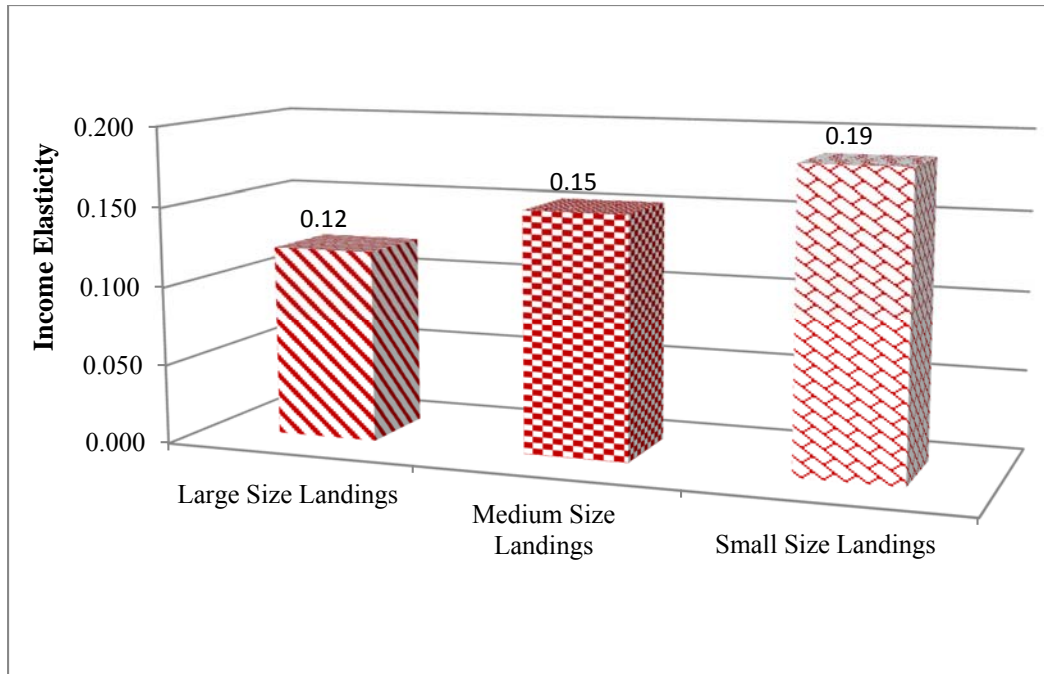
Figure 4.4. Income Elasticity of Inverse Demand during 1995(1)-2010(4).

Table 4.16. Income Elasticity Estimates for Inverse Demand, 1995(1)-2010(4).

Large Size Landings	Medium Size Landings	Small Size Landings
0.121*	0.152*	0.186**
0.026	0.038	0.089
4.68	4.01	2.08

*significant at 1% level

**significant at 5% level

***significant at 10% level

Without * means is not significant

As indicated in chapter 3, in order to satisfying the adding up constraint, the budget share weighted average of the income elasticities should sum to unity (Theil, 1987).

$$\sum_i \theta_i + \sum_r (-\gamma_r) = 1 \qquad \sum_i w_{ai}\eta_{ai} + \sum_r (w_{br}\eta_{br}) = 1 \qquad (4.13)$$

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To test that whether this restriction is imposed correctly, the sum of income elasticities for both ordinary and inverse demands are shown in table 4.17.

Table 4.17. Sum of Income Elasticities across Different Types of Shrimp Products, 1995(1)-2010(4).

	Income Elasticity	Mean share = mw	mw*IncElas
China	1.47	0.0465	0.0683
Ecuador	0.36	0.0976	0.0356
India	1.62	0.0574	0.0933
Indonesia	0.46	0.0719	0.0327
Mexico	1.58	0.0811	0.1277
Thailand	1.41	0.2856	0.4025
Vietnam	1.66	0.0723	0.1198
Other Countries	0.56	0.1866	0.1047
Large size landings	0.12	0.0362	0.0044
Medium size landings	0.15	0.0286	0.0044
small size landings	0.19	0.0361	0.0067
sum(mw*IncElas)=1		1.0000	**1.0000**

This restriction is imposed at mean values of corresponding budget shares. As table 4.17 presents the budget share weighted average of all income elasticities equal one, which indicates the adding up condition has been imposed, properly. Comparing column 3 and 4, each country and landings share in total expenditure is also changed after a 1% increase in U.S. expenditure on shrimp products.

4.3.5.7. Scale Elasticity of Ordinary Demand

The scale elasticity of regular demand measures the relations between the consumption of Gulf shrimp products (the ratio of quantity from one month to a month before), considered a bundle (including large, medium, and small sizes) and the ratio of the consumption for a selected country. In other words, these scale elasticities demonstrate the proportion change in the ratio of consumption for a selected country

due to a scale expansion in the consumption of Gulf shrimps' bundle. As presented in table 4.18, all these estimates are positive and statistically significant at a 1% level. The estimated scale elasticity for China, Ecuador, India, Indonesia, Mexico, Thailand, Vietnam, Other Countries equals 0.007, 0.002, 0.007, 0.002, 0.007, 0.006, 0.007, and 0.003 implying a 1% increase in the ratio of bundle of Gulf shrimp products raises the ratio of consumption for China, Ecuador, India, Indonesia, Mexico, Thailand, Vietnam, Other Countries shrimp exports to the U.S. increase by 0.007%, 0.002%, 0.007%, 0.002%, 0.007%, 0.006%, 0.007%, and 0.003%, respectively, holding all other factors constant.

Table 4.18. Scale Elasticity Estimates for Ordinary Demand, 1995(1)-2010(4).

	China	Ecuador	India	Indonesia	Mexico	Thailand	Vietnam	Other Countries
Estimate	0.007*	0.002**	0.007*	0.002**	0.007*	0.006*	0.007*	0.003*
Std Err	0.002	0.001	0.002	0.001	0.002	0.002	0.002	0.001
t Value	3.31	2.19	3.77	2.44	3.32	3.79	3.73	3.1

*significant at 1% level
**significant at 5% level
***significant at 10% level
Without * means is not significant

4.3.5.8. Scale Elasticity of Inverse Demand

These estimates are implying to the degree of change in Gulf shrimp dockside prices due to a scale expansion in the consumption of the Gulf shrimp bundle. These estimates are presented in table 4.19. As it is shown, all scale elasticities are negative. The Gulf large and medium size shrimps' scale elasticity of demand is statistically significant at a1% level, while the scale elasticity for small size Gulf shrimp is statistically significant at a 5% level. The scale elasticity of large size Gulf shrimp product is -0.03, indicating a 1% increase in the Gulf shrimp bundle will decrease the price of large size shrimp by 0.03%. The scale elasticity of demand for the medium and small size Gulf shrimps are -0.044 and -0.53, which imply that if the price of Gulf shrimp bundle goes up by 1%, the price of Gulf medium and small size

shrimp products will decrease by -0.044% and -0.53%, respectively. As indicated, these elasticities for demand are estimated at the ratio of price and quantity of demand rather than their levels.

Table 4.19. Scale Elasticity Estimates for
Inverse Demand, 1995(1)-2010(4)

Large Size Landings	Medium Size Landings	Small Size Landings
-0.023*	-0.028*	-0.035**
0.006	0.008	0.017
-3.65	-3.41	-1.99

*significant at 1% level
**significant at 5% level
***significant at 10% level
Without * means is not significant

CHAPTER 5
CONCLUSIONS AND POLICY IMPLICATIONS

This study has attempted to construct a more reliable specification for U.S. shrimp demand system. This study is the first case of a mixed Rotterdam demand system to provide theoretical and fundamental information about the U.S. shrimp industry. The results obtained from this study provide some fundamental information for the U.S. shrimp industry and policy makers, especially for the Gulf of Mexico shrimp industry specialists.

As indicated in previous chapters, since the 1980s U.S. shrimp imports have increased annually and represent 90% of total U.S. shrimp supply in recent decades. Specifically, increasing foreign supply has been associated with a reduction of the import price. United States shrimp market specialists are concerned that there is unfair price competition between domestic producers and shrimp exporting countries. The Southern Shrimp Alliance has open concept about unfair pricing several times during the last two decades. They filed an antidumping petition to stop unfair pricing by exporting countries in 2003. Following investigations by the Department of Commerce (DOC) and the United States International Trade Commission (USITC), they passed an antidumping law in six countries in January of 2005. However, antidumping duties have not helped domestic shrimp producers, processors, and distributors to obtain a larger share of the shrimp market.

Researchers have searched for reasons why the domestic shrimp market is unable to compete with exporting countries; however, this problem has remained unsolved. This study has adopted a new methodology to study the shrimp market. One of the advantages of this study is that it provides evidence of demand sensitivity with respect to a change in price of imports and U.S. expenditure on shrimp products by their source origin.

This author believes that shrimp imports and the domestic market have two different structures, which also means two different price/quantity relations. It has been shown that the annual production of shrimp from the Gulf of Mexico has remained relatively stable, during last two decades, while the dockside value of the Gulf shrimp has, overall, declined. However, in the shrimp import market along with increasing

the quantity of import the shrimp import price is decreasing. That means, the shrimp import market does not follow the same price/quantity relationship as the domestic shrimp market.

5.1. Implications for Methodology

One of the basic objectives of this study is to introduce a different approach that demonstrates a more realistic model of the U.S. shrimp market using a mixed demand system. To prove that this new method is able to determine U.S. shrimp market factors, a mixed Rotterdam demand specification has been adopted, which is associated with both ordinary and inverse demand functions. As the domestic supply has been stable over time, a quantity pre-determined framework, inverse demand, is considered for the domestic shrimp production, while a price pre-determined framework, regular demand, has been adopted for the shrimp import market. The results of this investigation have verified that a simple market structure, regular or inverse demand alone, cannot capture the complexity of the U.S. shrimp market. As expected theoretically, and shown in Chapter 4, the coefficient estimates of the regular demand, θ_i, are positive and the parameter estimates of the inverse demand, γ_r, are negative. This result cannot be obtained if one model, a regular or inverse demand function. For the U.S. shrimp market was applied. Price elasticity estimates of the ordinary/regular demand function also show that a mixed demand structure is more reliable for the U.S. shrimp market relative to a simple ordinary/regular demand or an inverse demand system. As indicated in Chapter 4, the own and cross price elasticities of regular demand are theoretically consistent and statistically significant. Specifically, the own-price elasticity of demand for each country is associated with a significant effect. This result is unattainable from regressing a regular demand, or an inverse demand, model alone, because, in such a model, the quantity of demand for imported shrimp will be considered an exogenous variable and the import prices do not involve in the model at all. The positive cross-price elasticities also imply that imported shrimp products are substitutes for one another. Jones et al.'s study reached a different conclusion and shows that shrimp imports are complementary goods. They adopted an inverse Netherlands Central Bureau Statistic demand system model (CBS). The author of this dissertation believes that an unexplainable conclusion may be the result of a misspecified model for the U.S. shrimp

market. Therefore, a mixed demand, and, in this study, a mixed Rotterdam demand, is a specification that can illustrate the U.S. shrimp market structure better than any parameterization of regular demand or an inverse demand.

5.2. Implications for Shrimp Demand Market

In this section, the results are organized into seven categories, which include anti-dumping parameter estimates, marginal budget share estimates, the price elasticities of ordinary/regular demands, the price elasticities of inverse demands, the quantity flexibilities/elasticities of regular demands, the income elasticities of ordinary demands, and the income elasticities of inverse demands.

5.2.1. Anti-dumping Parameter Estimates

As expected, the anti-dumping dummy variable parameter estimates revealed that these duties had negative effects on Ecuador and India's shrimp imports, though it had a positive effect on Mexico's shrimp imports. As indicated in previous chapters, the anti-dumping duties are imposed on six countries which include both Ecuador and India's shrimp imports, but not Mexico's shrimp imports. These results imply that anti-dumping duties had significant effect on the U.S. domestic shrimp market for imports from Ecuador, India, and Mexico. The anti-dumping coefficient estimates for other named countries in anti-dumping law, which are also included in this study are not statistically significant.

5.2.2. Marginal Budget Share Estimates

In Chapter 4, it is shown that Thailand has the largest share of U.S. expenditures on shrimp during 1995(1)-2010(4). This means that the United States is spending more of its shrimp income/expenditure on Thailand's exports relative to any other country's exports. Therefore, the price-quantity relationship between this country's exports to the United States and U.S. domestic shrimp products is an important issue. The estimated parameters for both regular and inverse demand are defined as marginal budget shares. These estimates lead to some important conclusions.

Thailand has the largest marginal shares among all countries and product types, while Mexico and Vietnam have the second largest shares. The marginal share coefficient measures the amount of money that the United States would spend on shrimp imports from a selected country, or selected size of Gulf product

in response to one dollar change in U.S. expenditures on shrimp. In this instance, one can conclude that United States spend more on Thailand, Mexico, and Vietnam shrimp products than other countries and domestic shrimp products. Again, this is the same conclusion that is obtained from summary statistics.

5.2.3. Price Elasticity of Ordinary Demand

Elasticity estimates reveal some important conclusions. The own-price elasticity estimates for China, India, Mexico, and Vietnam are almost similar in magnitude, implying that the price sensitivity of demand for these countries is approximately the same. In other words, an increase in these countries' shrimp export prices will have a similar impact on these countries' export quantities.

The cross-price elasticities present the effect of an increase in a country's export prices on other countries' quantity of exports. The result (shown in chapter 4) clearly indicates that Thailand's export prices have the largest effect on the quantity of other countries' exports to the United States. These findings refer to an important result; a change in Thailand's export prices will influence the other countries' export quantities relatively more than a change in other competing country's export prices. In other words, all country's quantity of exports is more sensitive to a change in Thailand's export prices than other countries prices.

Theoretically, the negative sign for the own-price elasticity of demand implies that a change in the price of exports causes the quantity of exports to decrease. Also, positive cross-price elasticity of demand indicates that there is a direct responsiveness between the price of export of a country and the quantity of export of another country, which indicate that imported shrimp products from different countries are substitute goods, as they are expected to be.

As indicated in Chapter 4, the author believes the only reason among all above reasons that makes Thailand different from China, India, Mexico, and Vietnam is the number of substitutions for the Thailand's shrimp. It seems Thailand's shrimp has fewer substitutes than China, India, Mexico, and Vietnam's shrimp products. Other factors such as time (the period of study) and income (the amount of money that U.S. spends on shrimp) are the same for these countries.

If the price elasticity of demand is less than one (in absolute value), it is said that the commodity is inelastic. This means that a change in the price of the good does not cause a large decline in demand. On the other hand, if the price elasticity of demand is greater than one, it is said that the good is elastic since even a small change in the price of good causes a sharp decrease in demand. The results obtained in this study indicate that demand for all countries' shrimp products is inelastic since they are less than one. Another important issue in this relationship is that Thailand's export-price sensitivity is not as high as that of some other countries like China and India. Therefore, according to the reason mentioned earlier, Thailand's shrimp products are relatively more inelastic than those of countries like China, India, Mexico, and Vietnam. In other words, consumers will more easily give up buying (or substitute) China's shrimp products than Thailand's shrimp products with an increase in the price of these countries' shrimp products.

5.2.4. Price Elasticity[12] of Inverse Demand

The price elasticity/flexibility of inverse demand reveals another important conclusion. No country's export prices have a significant effect on any size of Gulf landings. The most significant effect is about 0.02% on the price of small size Gulf landings for a 1% change in the price of Thailand's exports to the United States. The anti-dumping duties in 2005, which were imposed on six countries to compensate for the unfair import prices, did not have a long-term significant improvement for domestic shrimp market. However, among these countries, Thailand's export prices still have the most impact on domestic shrimp products' prices.

5.2.5. Quantity Elasticity of Ordinary Demand

The quantity flexibility/elasticity of inverse demand demonstrates the sensitivity of Gulf landings prices with respect to the volumes of landings. The own-quantity elasticities of Gulf landings are negative, implying that a change in Gulf landings will have a negative effect on Gulf landings' prices, which is consistent with consumer demand theory (law of demand). The cross-quantity elasticities are positive; this indicates that there are positive relations between the quantity of a selected size landings and the price of

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[12] As mentioned in Chapter 4, most authors that have worked with a mixed demand model have applied the elasticity term instead of flexibility term even for the inverse demand equations of the model.

all other sizes. As mentioned in Chapter 4 the quantity of landings has a small influence on Gulf dockside prices.

5.2.6. Income Elasticity of Ordinary Demand

One of the most important estimates from this study is the income elasticity of demand functions. According to Theil's definition, the income elasticity of demand measures the sensitivity of each country's shrimp exports to a change in U.S. expenditure on shrimp products.

Vietnam, India, Mexico, China, and Thailand's income elasticities are greater than one. Therefore, one can conclude that a change in U.S. expenditure on shrimp products not only increases the consumption of these countries shrimp imports but also the proportion (share) of these products increase relative to U.S. total expenditures on shrimp. The elasticity estimates indicate that the income sensitivity of U.S. demand for Thailand's shrimp products is less than that of some other countries such as Vietnam and India. The cross-price elasticities have also presented the same conclusion; income and price sensitivities of demand for India, Mexico, Vietnam, and China are higher than for Thailand. As previously stated, Thailand has the largest share of U.S. expenditures on shrimp products. For this reason, one can conclude that U.S. consumer do not easily substitute Thailand shrimp with any other country's shrimp even if the price of this county's shrimp products goes up.

According to the homogeneity condition the sum of own-price elasticity, cross-price elasticity, and income elasticity of demand for each country should be equal to zero. Thailand's own-price elasticity of demand is less than China, India, Mexico, and Vietnam's own-price elasticity of demand. Also it is presented that Thailand's cross-price elasticity of demand is larger than these countries, while its income elasticity is approximately the same. Therefore, the results indicate Thailand has some degree of market power in the U.S. shrimp industry. This result can be added to the conclusion that was made in chapter 4: Lerner Index and Thailand's largest share in U.S. total expenditures on shrimp reveals an important conclusion indicating Thailand dominance in the U.S. shrimp market.

5.2.7. Income Elasticity of Inverse Demand

Income elasticity for inverse demand demonstrates the sensitivity of Gulf dockside price with respect to a change in U.S. expenditure on shrimp products. As mentioned in Chapter 4, Gulf dockside prices sensitivity relative to a change in U.S. expenditure on shrimp is less than one. This means, for example, that if U.S. expenditure on shrimp products increases by 100%, the large, medium, and small size landings' prices will increase by12%, 15%, and 19%, respectively.

5.3. Implications for Future Research

The model presented in this dissertation has evolved from several previous studies of the shrimp market and mixed demand system areas. This author believes that some theoretical and statistical characteristics of the presented model can be appealing for future studies. For example, researchers can modify this model for the U.S. shrimp demand market by applying different shrimp product forms such as peeled frozen, breaded frozen and canned shrimp.

Another aspect to future research could concentrate on the U.S. shrimp imports by product forms, as well as their source origin. In this study several important results trace back to consumers' preferences. For example, Thailand has the largest share of U.S. expenditures on shrimp. Also the price and income sensitivity of demand for Thailand's shrimp is less than some other countries such as China and India. As these issues refer to consumer preferences, the question arises as who are the largest consumers of shrimp products in the United States such as individuals, restaurants, or processors. Are individuals aware of and/or care about the origin of shrimp imports? To answer such questions, a study that can provide some information about the distribution of shrimp buyers in the U.S. would be useful.

In this study, direct and indirect utilities preference independence restrictions were added to the mixed Rotterdam demand system. More constraints, such as block independence preference, can also be imposed on the demand system which is less restricted than the preference independence constraint imposed on the mixed Rotterdam demand system in this study. Under block preference independence restriction, it is assumed that the additive specification (equation 3.35, in chapter 3) is applied to two commodity groups "a" and "b" instead of each individual good. Accordingly, two commodities that belong to two different

groups are neither substitute nor complementary. Imposing this restriction allows one to test whether domestic shrimp (Gulf of Mexico landings) and imported shrimp are true substitute goods or not.

REFERENCES

Adams, C. M., Prochaska, F. J., & Spreen, T. H. (1987). Price determination in the U.S. shrimp market. *Southern journal of agricultural economics,19* (2), 103-112.

Adams, C. M. (1084). Price dynamics in the U.S. shrimp market. (Unpublished Ph.D. dissertation). Food and resource economics department. University of Florida, Gainesville, FL.

Asche, F., Bennear, L. S., Oglend, A., & Smith, M. D. (2011). U.S. Shrimp Market Integration. *Marine Resource Economics, 27(2), 181-192.*

Barbier, E. D., & Cox, M. (2004). An economic analysis of shrimp farm expansion and mangrove conversion in Thailand. *Land Economics, 80* (3), 389-407.

Barten, A.P. (1969). Maximum likelihood estimation of a complete system and demand equations. *Eurpean Economic Review, 1* (1), 7-73.

Barten , A.P. (1992). The estimation of mixed demand system. In R. Bewley and Tran Van Hoe, eds. Contributions to consumer demand and econometrics: Essay in Honour of Henri Theil, London: Macmillan, 31-57.

Barten, A.P., & L.J. Bettendorf. (1989). Price formation of fish: An application of an inverse demand system. *European economic review, 33* (8), 1509-1525.

Berndt, E.R., & N.E. Savin. (1975). Estimation and hypothesis testing in singular equation systems with autoregressive disturbances. *Econometrica, 43* (5), 937-957.

Barnett, W.A. (1979). Theoreticla foundations for the Rotterdam model. *The review of economic studies, 46* (1), 109-130.

Brown, M., & Lee, J. (1997). Incorporating generic and brand advertising effects in the Rotterdam demand system. *International Journal of Advertising, 16* (3), 211–220.

Brown, M.G., & J.Y. Lee. (2006). A mixed Rotterdam demand system. In M. Holt and J.P. Chanvas, eds. Essay in Honor of Stanley R. Johnson. Berekley Electroinc Press, Atricle 14. Retrieved from http://www.bepress.com/siohnson/art14/.

Brown, M. G. & Lee, J. Y. (2000). Restrictions on the effects of preference variables in the Rotterdam model. *Journal of Agricultural and Applied Economics, 34* (l), 17-26.

Brown, M. G. & Lee, J. Y. (2000). A Measurement of the quality of orange-juice consumption. *Agribusiness, 16* (3), 321–332.

Bruce N. (1977). A Note on consumer's surplus, the Divisia Index, and the measurement of welfare changes. *Econometrica, 45* (4), 1033-1038.

Cato, J.C., and C. A. Lima dos Santos. 2000. Costs to Upgrade the Bangladesh Frozen Shrimp Processing Sector to Adequate Technical and Sanitary Standards and to Maintain a HACCP Program. In The Economics of HACCP: New Studies of Costs and Benefits, pp. 385-402, St. Paul, MN.

Cato, J. C., (2004). An overview of the Bangladesh shrimp industry with emphasis on the safety and quality of exported products, prepared for the World Bank.

Chalfant, J.A. (1987). A globally flexible, Almost Ideal demand system. *Journal of business & economic statistic, 5* (2), 233-242.

Chavas, J.P. (1984). The theory of mixed demand functions. *European economic review*, 24 (3), 321-344.

Cleary, D. P. (1969). Demand and price structure for shrimp. Working paper (15). Bureau of Commercial Fisheries, Division of Economic Research. Wshington, D.C.

Cornes, R. (1980). External effects: An alternative formation. *European Economic Review, 14* (3), 307-321.

Cunha-e-Sa, M.A., & M.M. Ducla-Soares. (1999). Specification test for mixed demand system with an emphasis on combining contingent valuation and revealed data. *Journal of environment economics and management, 38* (2), 215-233.

Deaton, A. S. (1981). Optimal taxes and the structural of preferences. *Econometrica, 49* (5), 1245-1260.

Deaton, A.S. & J. Muellbauer, (1980). An Almost Ideal demand system. *American economic review, 70* (3), 312-326

Diop, H., Harrison, R. W., & Keithly, W. R. (1999, Agust). Impact of increasing imports on the United States Southeastern region shrimp processing industry 1973-1996. Paper presented at the annual meeting of the American Agricultural Economics Association, Nashville, TN.

Doll, J. P. (1972). An econometric analysis of shrimp ex-vessel prices 1950-1968. *American journal of agricultural economics, 54* (3), 431-440.

Duffy, M. H. (1990). Advertising and alcoholic drink demand in the UK: Some further Rotterdam model estimates. *International journal of advertising*, 9 (2), 247–257.

Food and Agriculture Organization of the United Nations (2009), The state of food and agriculture. Retrieved from http://www.fao.org/docrep/012/i0680e/i0680e.pdf

Frisch, R. (1959). A complete scheme for computing all direct and cross demand elasticities in a model with many sectors. *Econometrica*, 27 (2), 177-196.

Gao, X. M., Wailes, E. J., & Cramer, G. L. (1996). Partial rationing Chinese urban household food 99emand analysis. *Journal of comparative economics, 22* (1), 43-62.

Gary Wong, K. K., & Park, H. (2007). The use of conditional cost functions to generate estimable mixed demand systems. *American journal of agricultural economics, 89* (2), 273–286.

Gillespie, W. C., Hite J. C., & Lytle J. S. (1969). An econometric analysis of the U.S. shrimp Industry. Department of agricultural economics and rural sociology, Agricultural experiment station, Clemson University, Clemson, SC.

Haas, H. L., Lamon, E. C., Rose, K. A., and Shaw, R. F. (2001). Environmental and biological factors associated with the stage-specific abundance of brown shrimp (*Penaeus aztecus*) in Louisiana: Applying a

new combination of statistical techniques to long-term monitoring data. *Canadian journal of fisheries and aquatic science, 58* (11) 2258–2270.

Haas, H.L., Shaw, R.F., Rose, K.A., Benfield, M.C., & Keithly Jr., W.R. (1999, November). Regression analysis of the relationships among life stage abundances of brown shrimp (Penaeus aztecus) and environmental variables in southern Louisiana, USA. Paper presented at the fifty second annual Gulf and Caribbean Fisheries Institute, Key West, FL.

Heien, D. (1977). Price determination processes for agricultural sector models. *American journal of agricultural economics, 59* (1), 126-132.

Houck, J.P. (1965). The relationship of direct price flexibilities to direct price elasticities. *Journal of farm economics, 47* (3), 789-792.

Houston, J. E., & Nieto A. E. (1988). "Regional shrimp market responses to domestic landings and imports." *Journal of Food Distribution Research*, *19* (1), 99-107.

Houston, J. E., Nieto, A. E., Epperson, J. E., LI, H. S., Lewis, G. W. (1989). Factors affecting local prices of shrimp landings. *Marine resource economics, 6* (2), 163-172

Houthakker, H. S. (1952). Compensated changes in quantities and qualities consumed. *The review of economic studies, 19* (3), 155–164.

Huang, K. S. (2006, August). A look at food price elasticities and flexibilities. Poster paper presented at the International Association of Agricultural Economists Conference, Gold Coast, Australia.

Jones, K., Harvey, D. J., Hahn, W. F., & Muhammad A. (2008). U.S. Demand for source-differentiated shrimp: A differential approach. *Journal of agricultural and applied economics, 40* (2), 609-621.

Keithly JR., W. R., & Poudel, P. (2008). The Southeast U.S.A. shrimp industry: Issues related to trade and antidumping duties. *Marine resource economics, 23* (4), 459–483.

Keller, W.J., & Van Driel, J. (1985). Differential consumer demand systems. *European economic review, 27* (3), 375-390.

Lee, J. Y. & Brown, M. G. (1996). The potential for high-value agricultural products under the north American free trade agreement: The case of beef in Mexico and Canada: Comment. *Journal of Agricultural and Applied Economics, 28* (2), 453-454.

McLaren K. R., & Gary Wong, K. K. (2009). Effective global regularity and empirical modelling of direct, inverse, and mixed demand systems. *Canadian journal of economics, 42* (2), 749-770.

Madden, D. (1993). "A new Set of consumer demand estimates for Ireland." *The economic and social review, 24* (2), 101-123.

Matsuda, T. (2004). Incorporating generalized marginal budget shares in a mixed demand system. *American journal of agricultural economics, 86* (4), 1117-1126.

Moschini, G., Vissa, A. (1992). A linear inverse demand system. *Journal of agricultural and resource economics, 17* (2), 294-302.

Moschini, G. and A. Vissa. (1993). Flexible specification of mixed demand system. *American journal of agricultural economics,75* (1), 1-9.

Moschini, G. (1998). The semiflexible almost ideal demand syatem. *European economic review, 42* (2), 349-364.

Moschini, G. and P.L. Rizzi. (2006). Coherent specification of a mixed demand system: The stone-geary model.: In M. Holt and J.-P. Chavas, eds. Essay in Honor of Stanley R. Johnson. Berkeley Electronic Press, Article 15. Available at http//www.bepress.com/sjohnson/art15/.

Moschini, G. and P.L. Rizzi, 2007. AJAE Appendix: Deriving a flexible mixed demand system: The normalized quadratic model. (Unpublished manuscript). Retrieved from http://agecon.lib.umn.edu.

Moschini, G. and P.L. Rizzi. (2007). Deriving a flexible mixed demand system: The normalized quadratic model. *American journal of agricultural economics, 89* (4), 1034–1045.

Nance, J. M. (2004). Estimation of Effort in the Offshore Shrimp Trawl Fishery of the Gulf of Mexico. NOAA Fisheries, SEFSC Galveston Laboratory. Red Snapper SEDAR Data Workshop.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (1995). *Fisheries of the United States, 1995.*
Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus95/index.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (1996). *Fisheries of the United States - 1996.*
Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus96/index.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (1997). *Fisheries of the United States - 1997.*
Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus97/index.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (1998). *Fisheries of the United States - 1998.*
Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus98/index.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (1999). *Fisheries of the United States - 1999.*
Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus99/index.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (2000). *Fisheries of the United States - 2000.*
Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus00/index.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (2001). *Fisheries of the United States - 2001.*
Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus01/index.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service (2002). *Fisheries of the United States - 2002.*
Retrieved from http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/fus02/index.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service/The Status of U.S. fisheries (2010). Retrieved from http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm.

National Oceanic and Atmospheric Administration, NOAA (2003 and 2010).
Retrieved from www.noaa.gov/fisheries.html.

National Oceanic and Atmospheric Administration, National Marine Fisheries Service: Office of Science and Technology (2010).
Retrieved from www.st.nmfs.noaa.gov/st5/publication/.../gulf_summary_econ.pdf.

National Oceanic and Atmospheric Administration, NOAA (2003).
Retrieved from http://www.nmfs.noaa.gov/mediacenter/index.html.

Park, H., & Thurman W. N. (1999). On interpreting inverse demand systems: A primal comparison of scale flexibilities and income elasticities. *American journal of agricultural economics, 81* (4), 950-958.

Pindyck, R. S. & Rubinfeld, D. L. (2008). *Econometric models & economic forcasts* (4th ed.). New York City: McGraw-Hill publishing company.

Pollak R. A. (1969). Conditional demand functions and consumption theory. *The quarterly journal of economics*, 83 (1), 60-78.

Pollak, R.A., & Wales, T. J. (1991). The likelihood dominance criterion: A new approach to model selection. *Journal of Econometrics, 47* (2), 227-242.

Paulus J. D. (1975). Mixed estimation of a complete system of consumer demand equations. *Annals of economic and social measurement, 4* (1), 117-132.

Rhodes, R. J., Green, V. N., & Sandifer, P.A. (1990, Decmber). Whole marine shrimp usage and preferences in the United States wholesale market sector. *Florida Sea Grant College Program.* Paper presented at the Proceedings of the 15th Annual Conference of the Tropical and Subtropical Fisheries Technological Conference of the Americas: in second joint meeting with Atlantic Fisheries Technology Conference (pp. 449-463). University of Florida: Gainesville, FL.

Ran T. (2008). *Three papers on the behavior modeling of the shrimp fishermen in the Gulf of Mexico.* (Doctoral dissertation). Louisiana State University, Baton rouge, LA.

Samuelson, P.A. (1965). Using full duality to show that simultaneously additive direct and indirect utilities implies unitary price elasticity of demand. *Econometrica, 33* (4), 781-796.

Saravanan, M.R., Santhanam, K.L., (2008). *International Encyclopedia of Fishery Science and Technology,* (1st ed). New Delhi, India: Scientific Pub. Academy.

Testimony of Kristen Baumer, Paul Piazza and Sons (2005).
Retrieved from http://www.appropriations.senate.gov/ht-homeland-security.cfm?

Theil, H. (1975). *The theory and measurement of consumer demand: vol. 1.* Amsterdam: North-Holand.

Theil, H. (1976). *The Theory and Measurment of Consumer Demand: vol. 2.* Amsterdam: North-Holand.

Theil, H. & Clements, K. W. (1987). *Applied Demand Analysis: vol.7.* Cambridge, Massachusetts.

Thompson, M. E., & Roberts K. J. (1983). An econometric analysis of the U.S. shrimp market. Center for wetland resources, Louisiana State University, Baton Rouge, LA.

Thompson, M.E. and Roberts, K.J., (1982). Forecasting ex-vessel prices for the northern Gulf (8223). Louisiana State University, Baton Rouge, LA: Technical information service, U.S. department of commerce, NOAA.

Tyson, K. S., & Yanagida, J. F. (1984). Dynamic adjustment models for estimating shrimp consumption characteristics. *Journal of food distribution research*, *15* (2), 10-15.

U.S. Environmental Protection Agency/Gulf of Mexico Program (2010).
Retrieved from http://www.epa.gov/gmpo/about/facts.html.

Ward, J.M., Ozuna Jr, T., & Griffin W. L. (1995). Cost and revenues in the Gulf of Mexico shrimp fishery (NMFS-SEFSC, 371). Miami, FL: U.S. dept. of commerce,,NOAA.

Ward, J.M. (1988). A synthesis of cost and revenue surveys for Gulf of Mexico shrimp vessels. *Marine fisheries review, 50* (1), 47–52.

Wirth, F. F., & Davis, K. J. (2002, February). Shrimp purchasing behavior and preferences of seafood dealers. Paper presented at the Southern agricultural economics association annual meeting, Mobile, Al.

Wirth,F. F., Dugger, D. M., & Creswell, L. (2004, Decmber). Commercial scale penaeid shrimp demonstration in Inland freshwater systems. Final project report for Cost Reimbursable Contract 007188 between FL DACS, Division of Aquaculture and University of Florida, IFAS.

Wooldridge, J.M., (2008). *Introductory econometrics: A modern approach*, (4th ed.). Cincinnati, Ohio: South Western Educational Publishing.

World Bank, GDP Growth (annual %) (2013).
Retrieved from http://data.worldbank.org/country/united-states.

APPENDIX I
PREFERENCE INDEPENDENCE

$$w_{ai}Dq_{ai} = \theta_i DQ + \phi \sum_j (\theta_{ij} - \theta_i \theta_j - \theta_i \sum_s \gamma_s v_{ab}^{*sj}) Dp_{aj} + \phi \sum_s (-\sum_j \theta_{ij} U_{ab}^{*js} + \theta_i \sum_j \theta_j U_{ab}^{*js} + \theta_i \gamma_s) Dq_{bs},$$

$$w_{ai}Dq_{ai} = \theta_i DQ + \phi \sum_j (\theta_{ij} - \theta_i \theta_j) Dp_{aj} + \phi \sum_s \theta_i \gamma_s Dq_{bs}$$

$$w_{ai}Dq_{ai} = \theta_i DQ + \phi \sum_j \theta_{ij} Dp_{aj} - \phi \theta_i \sum_j \theta_j Dp_{aj} + \phi \theta_i \sum_s \gamma_s Dq_{bs}$$

$$w_{ai}Dq_{ai} = \theta_i DQ + \phi \theta_i (Dp_{aj} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs}) \qquad (3.18a)$$

$$w_{br}Dp_{br} = -\gamma_r DQ + \phi \sum_j (\sum_s \gamma_{rs} V_{ab}^{*js} + \gamma_r \theta_j + \gamma_r \sum_s \gamma_s V_{ab}^{*sj}) Dp_{aj} + \phi \sum_s (-\gamma_{rs} - \gamma_r \sum_j \theta_j U_{ab}^{*js} - \gamma_r \gamma_s) Dq_{bs},$$

$$w_{br}Dp_{br} = -\gamma_r DQ - \phi \gamma_r \sum_j \theta_j Dp_{aj} + \phi \sum_s (-\gamma_{rs} - \phi \gamma_{br} \sum_s \gamma_s) Dq_{bs}$$

$$w_{br}Dp_{br} = -\gamma_r DQ - \phi \gamma_r (Dq_{br} - \sum_j \theta_j Dp_{aj} + \sum_s \gamma_s Dq_{bs}) \qquad (3.18b)$$

Variables and their Definitions

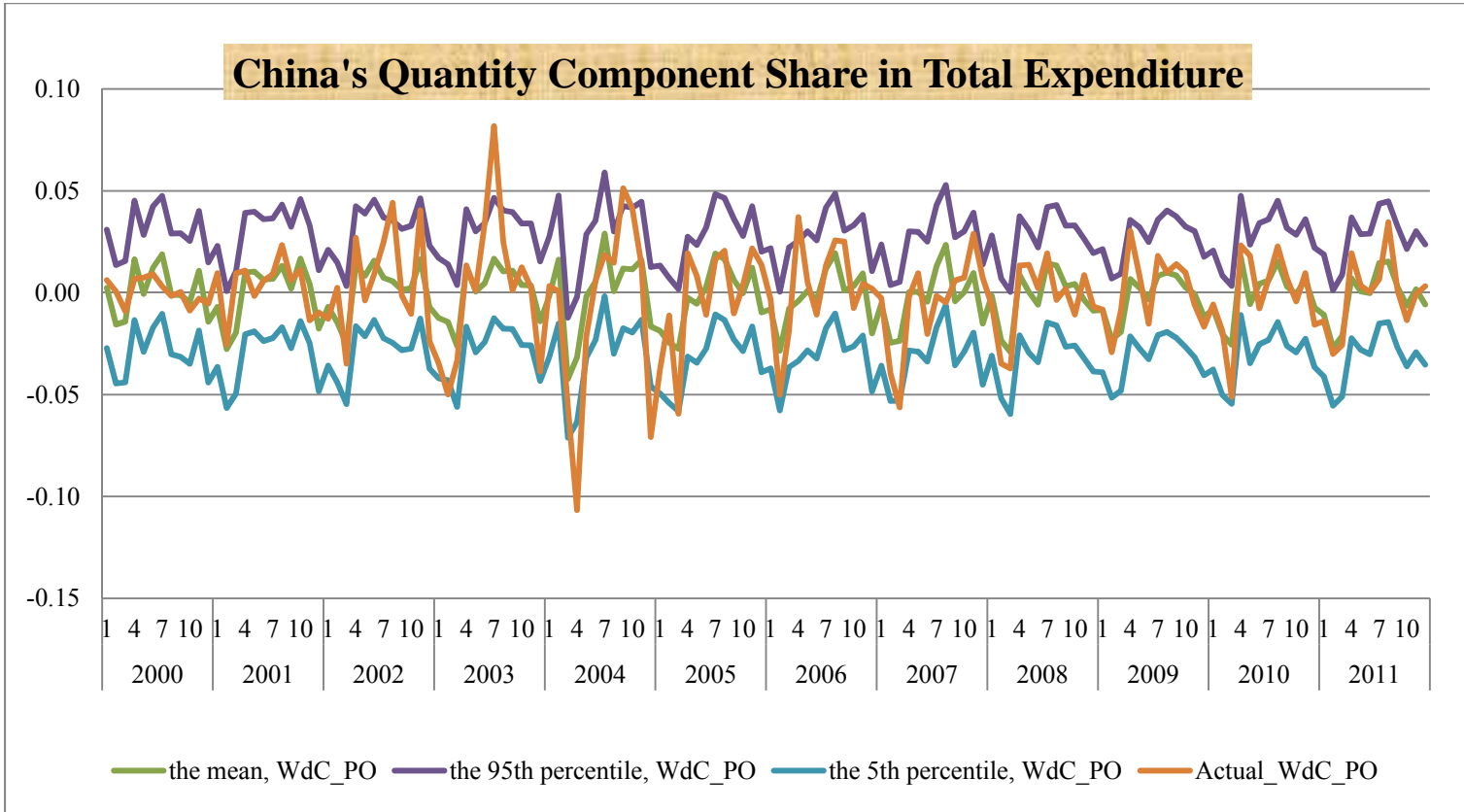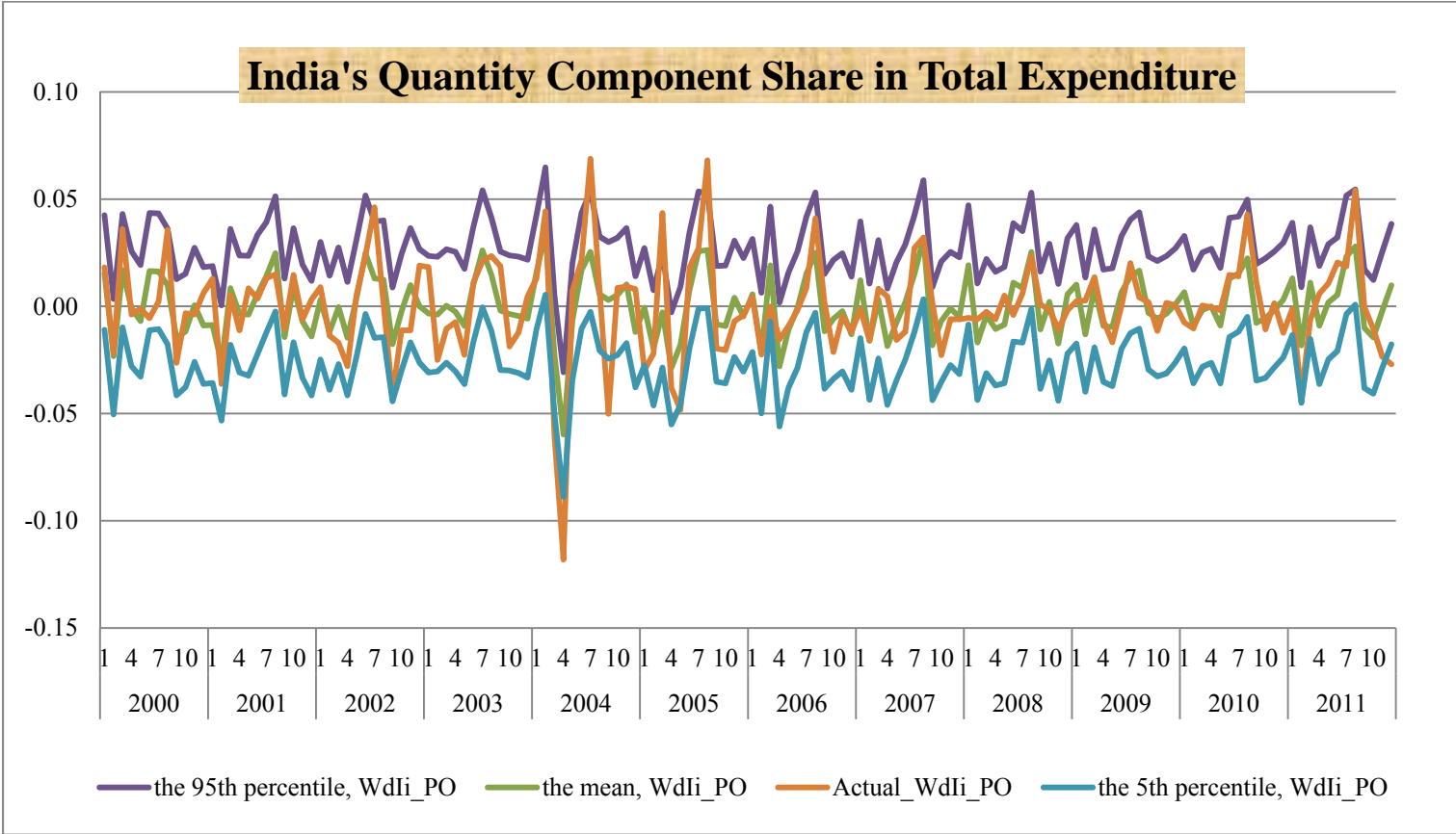| Variable	Definition	Variable Type
Chi_PO	China's imports to the U.S. in Pound	Dependent variable
Chi_PPP	China's imports to the U.S. Dollar_Value	Independent variable
Ecu_PO	Ecuador's imports to the U.S. in Pound	Dependent variable
Ecu_PPP	Ecuador's imports to the U.S. in Dollar_Value	Independent variable
Indi_PO	India's imports to the U.S. in Pound	Dependent variable
Indi_PPP	India's imports to the U.S. in Dollar_Value	Independent variable
Indo_PO	Indonesia's imports to the U.S. in Pound_Volume	Dependent variable
Indo_PPP	Indonesia's imports to the U.S. Dollar_Value	Independent variable
Mex_PO	Mexico's imports to the U.S. in Pound_Volume	Dependent variable
Mex_PPP	Mexico's imports to the U.S. DollR_Value	Independent variable
Thi_PO	Thailand's imports to the U.S. in Pound_Volume	Dependent variable
Thi_PPP	Thailand's imports to the U.S. Dollar_Value	Independent variable
Vie_PO	Vietnam's imports to the U.S. in Pound_Volume	Dependent variable
Vie_PPP	Vietnam's imports to the U.S. Dollar_Value	Independent variable
Other_PO	All Other Countries's imports to the U.S. in Pound_Volume	Dependent variable
Other_PPP	All Other Countries's imports to the U.S. Dollar_Value	Independent variable
L1_PO	Gulf Large_Shrimp Ladings in Pound_Volume, Size 1, 2, 3	Independent variable
L1_PPP	Gulf Large_Shrimp Ladings Price per Pound, Size 1, 2, 3	Dependent variable
L2_PO	Gulf Medium_Shrimp Ladings in Pound_Volume, Size 4, 5, 6	Independent variable
L2_PPP	Gulf Medium_Shrimp Ladings Price per Pound, Size 4, 5, 6	Dependent variable
L3_PO	Gulf Small_Shrimp Ladings in Pound_Volume, Size 7, 8	Independent variable
L3_PPP	Gulf Small_Shrimp Ladings Price per Pound, Size 7, 8	Dependent variable

Variables and their Definitions

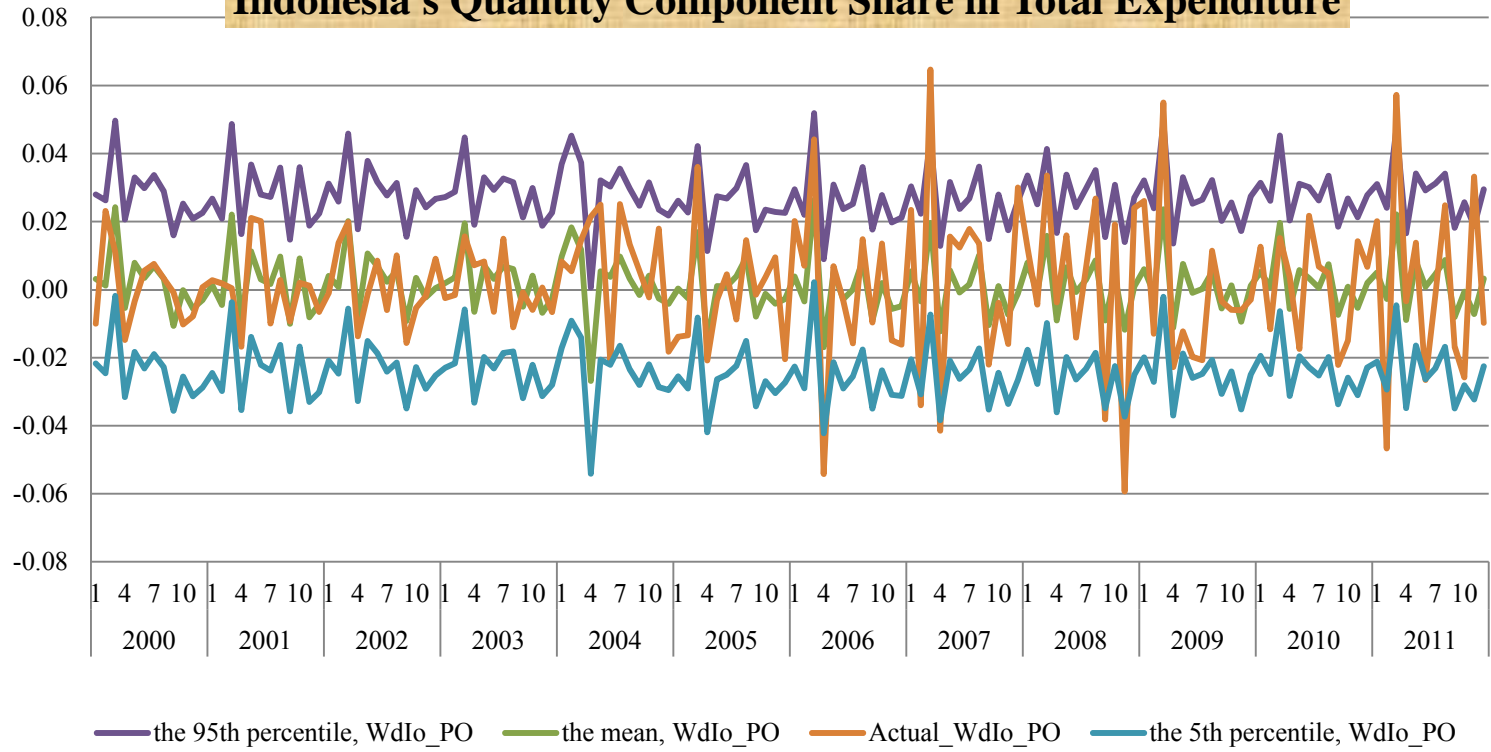| Variable	Definition
WdC_PO	China'sMean Budget Share * log (Chi_PO/lag(Chi_PO))
WdC_PPP	China's Mean Budget Share * log (Chi_PPP/lag(Chi_PPP))
WdE_PO	Ecuador's Mean Budget Share * log (Ecu_PO/lag(Ecu_PO))
WdE_PPP	Ecuador's Mean Budget Share * log (Ecu_PPP/lag(Ecu_PPP))
WdIi_PO	India's Mean Budget Share * log (Indi_PO/lag(Indi_PO))
WdIi_PPP	India's Mean Budget Share * log (Indi_PPP/lag(Indi_PPP))
WdIo_PO	Indonesia's Mean Budget Share * log (Indo_PO/lag(Indo_PO))
WdIo_PPP	Indonesia's Mean Budget Share * log (Indo_PPP/lag(Indo_PPP))
WdM_PO	Mexico's Mean Budget Share * log (Mex_PO/lag(Mex_PO))
WdM_PPP	Mexico's Mean Budget Share * log (Mex_PPP/lag(Mex_PPP))
WdT_PO	Thailand's Mean Budget Share * log (Thi_PO/lag(Thi_PO))
WdT_PPP	Thailand's Mean Budget Share * log (Thi_PPP/lag(Thi_PPP))
WdV_PO	Vietnam's Mean Budget Share * log (Vie_PO/lag(Vie_PO))
WdV_PPP	Vietnam's Mean Budget Share * log (Vie_PPP/lag(Vie_PPP))
WdO_PO	All Other Countries's Mean Budget Share * log (Other_PO/lag(Other_PO))
WdO_PPP	All Other Countries's Mean Budget Share * log (Other_PPP/lag(Other_PPP))
WdL1_PO	Gulf Large Shrimp Ladings Mean Budget Share * log (L1_PO/lag(L1_PO))
WdL1_PPP	Gulf Large Shrimp Ladings Mean Budget Share * log (L1_PPP/lag(L1_PPP))
WdL2_PO	Gulf Medium Shrimp Ladings Mean Budget Share * log (L2_PO/lag(L2_PO))
WdL2_PPP	Gulf Medium Shrimp Ladings Mean Budget Share * log (L2_PPP/lag(L2_PPP))
WdL3_PO	Gulf Small Shrimp Ladings Mean Budget Share * log (L3_PO/lag(L3_PO))
WdL3_PPP	Gulf Small Shrimp Ladings Mean Budget Share * log (L3_PPP/lag(L3_PPP))

China's Quantity Component Share in Total Expenditure

Ecuador's Quantity Component Share in Total Expenditure

the mean, WdE_PO   the 95th percentile, WdE_PO   the 5th percentile, WdE_PO   Actual_WdE_PO

India's Quantity Component Share in Total Expenditure

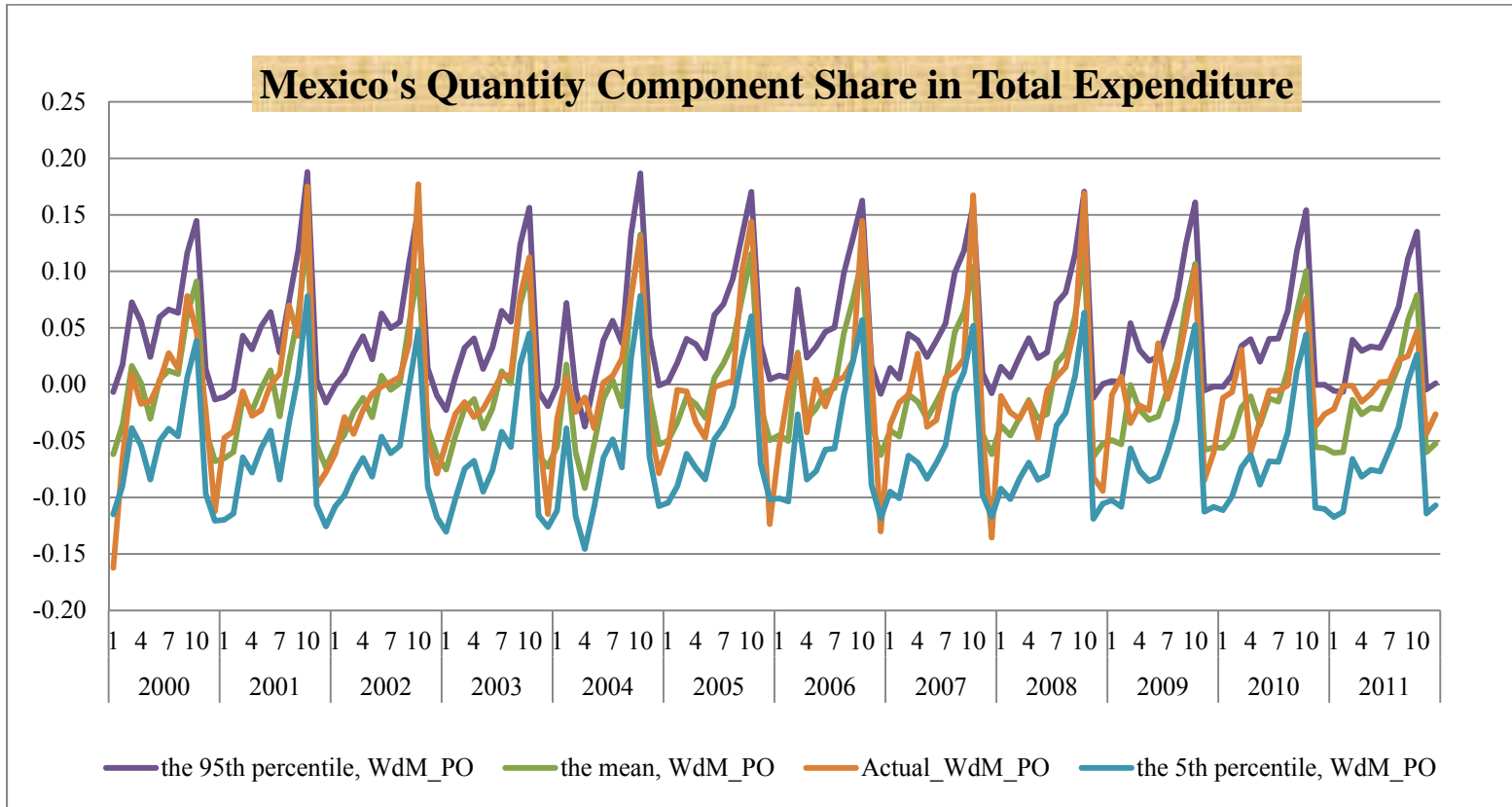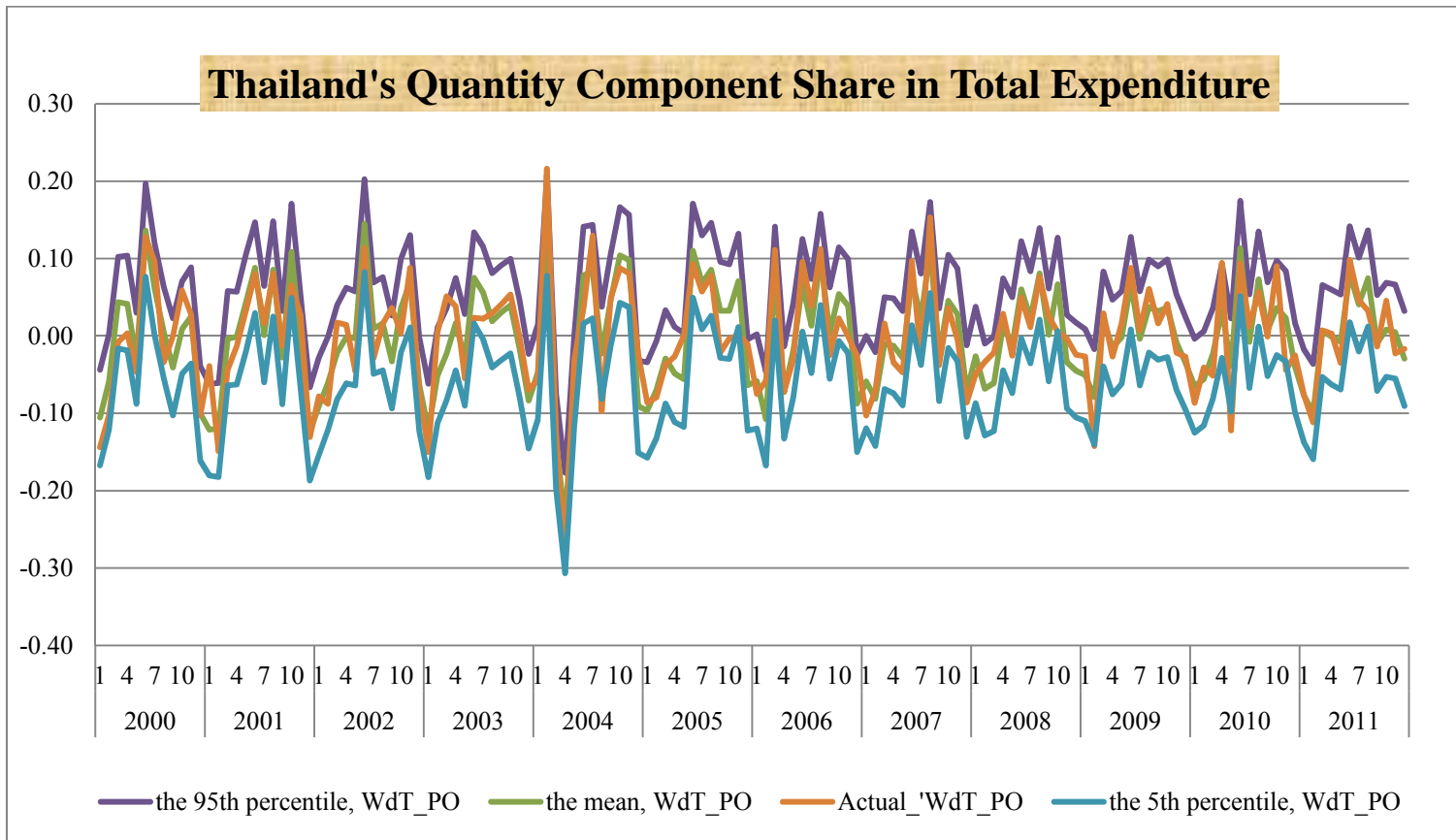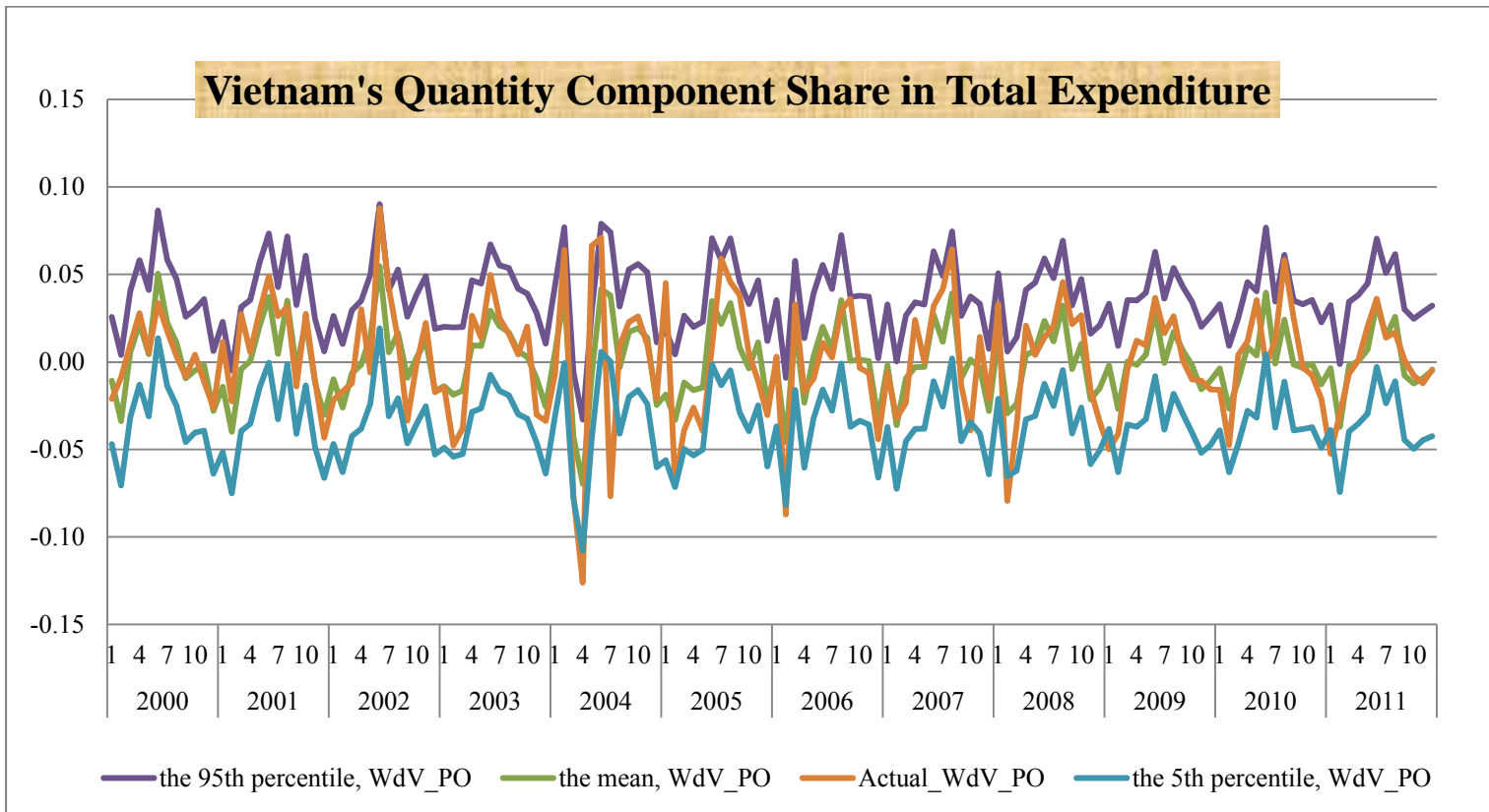the 95th percentile, WdIi_PO — the mean, WdIi_PO — Actual_WdIi_PO — the 5th percentile, WdIi_PO
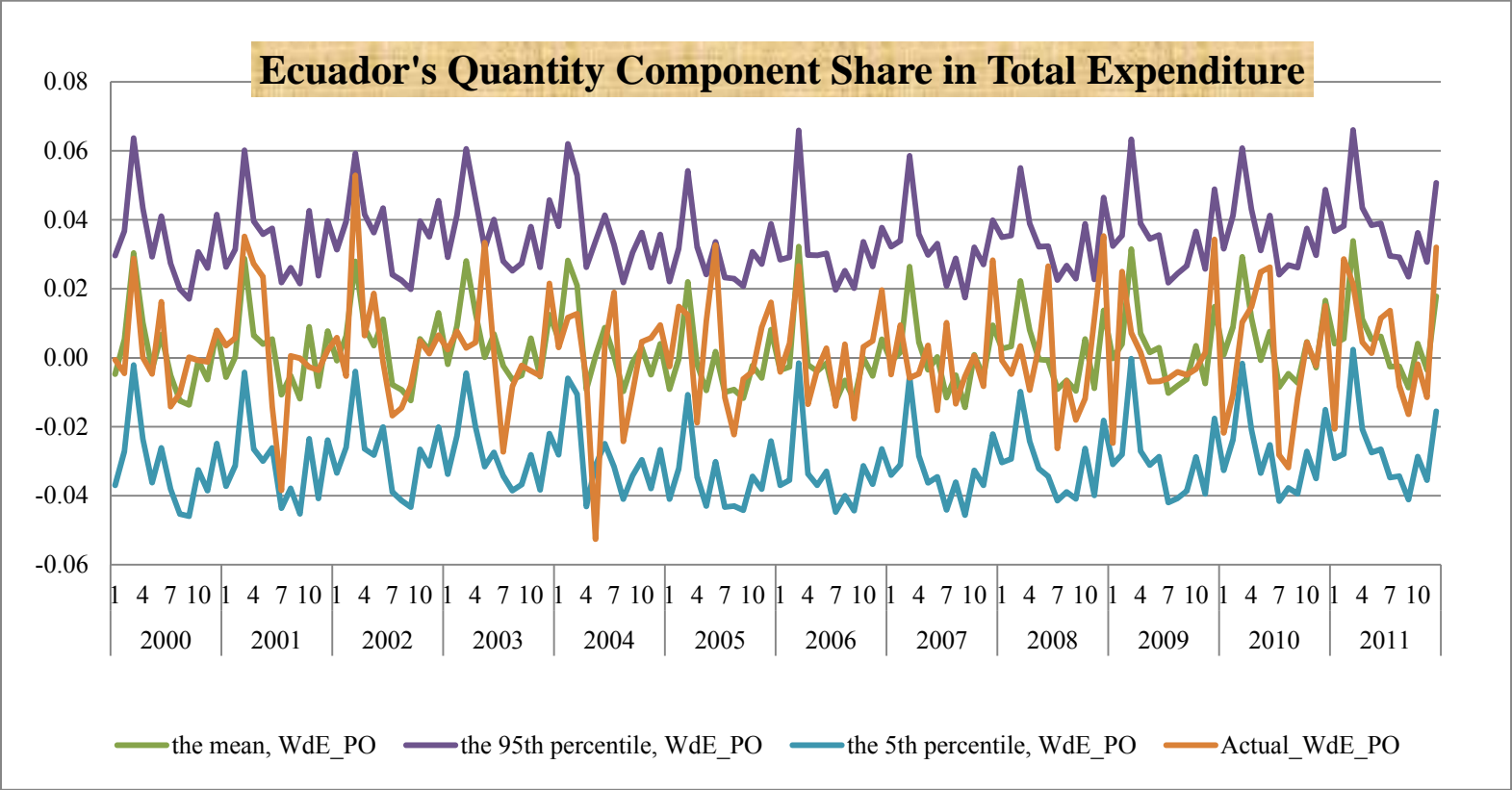
Indonesia's Quantity Component Share in Total Expenditure

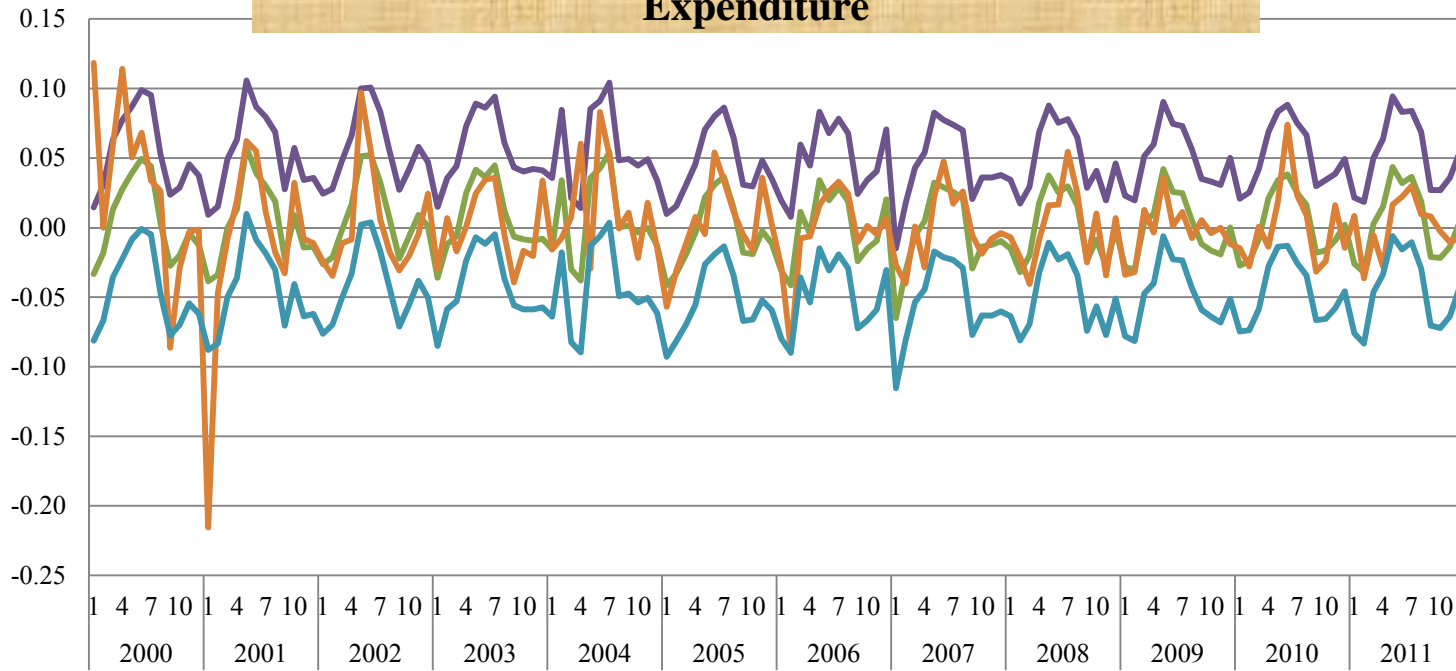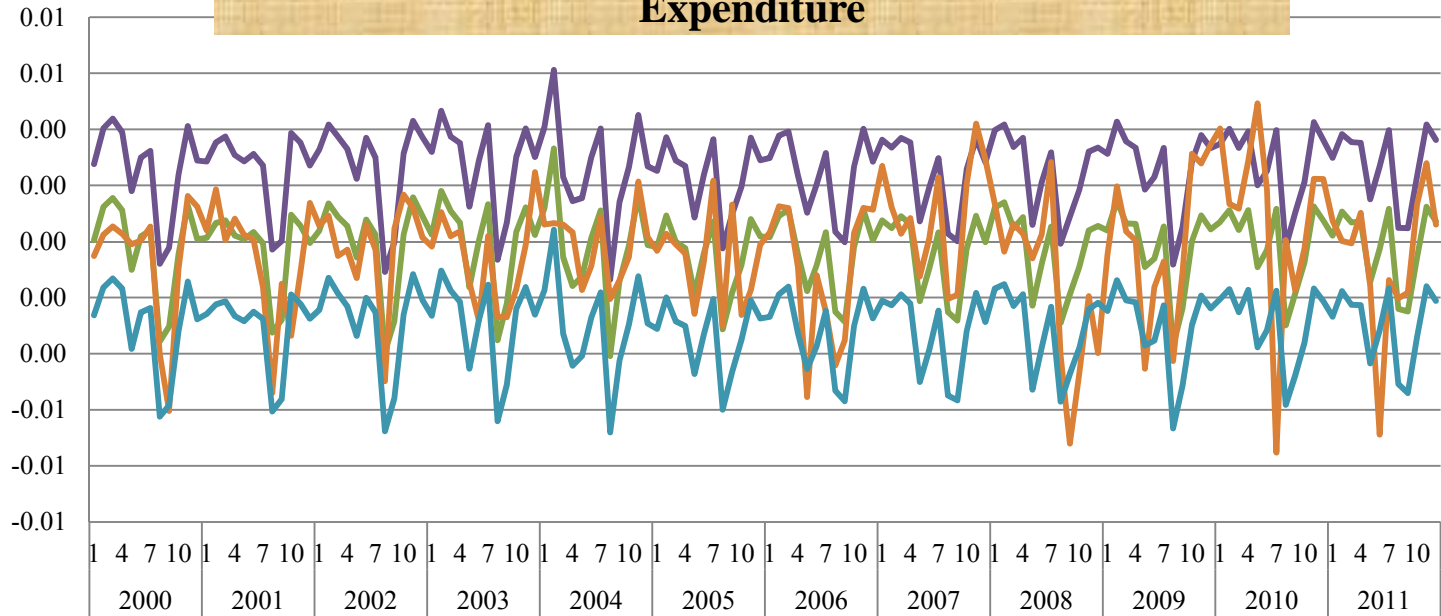the 95th percentile, WdIo_PO — the mean, WdIo_PO — Actual_WdIo_PO — the 5th percentile, WdIo_PO

Mexico's Quantity Component Share in Total Expenditure

Legend: the 95th percentile, WdM_PO — the mean, WdM_PO — Actual_WdM_PO — the 5th percentile, WdM_PO

Thailand's Quantity Component Share in Total Expenditure

— the 95th percentile, WdT_PO   — the mean, WdT_PO   — Actual_'WdT_PO   — the 5th percentile, WdT_PO

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Vietnam's Quantity Component Share in Total Expediture

the 95th percentile, WdV_PO   the mean, WdV_PO   Actual_WdV_PO   the 5th percentile, WdV_PO

**Other Countries's Quantity Component Share in Total Expenditure**

the 95th percentile, WdO_PO   the mean, WdO_PO   Actual_WdO_PO   the 5th percentile, WdO_PO

Gulf Large Size Shrimp's Price Component Share in Total Expenditure

Gulf Medium Size Shrimp's Price Component Share in Total Expenditure

Legend: the 95th percentile, WdL2_PPP — the mean, WdL2_PPP — Actual_WdL2_PPP — the 5th percentile, WdL2_PPP
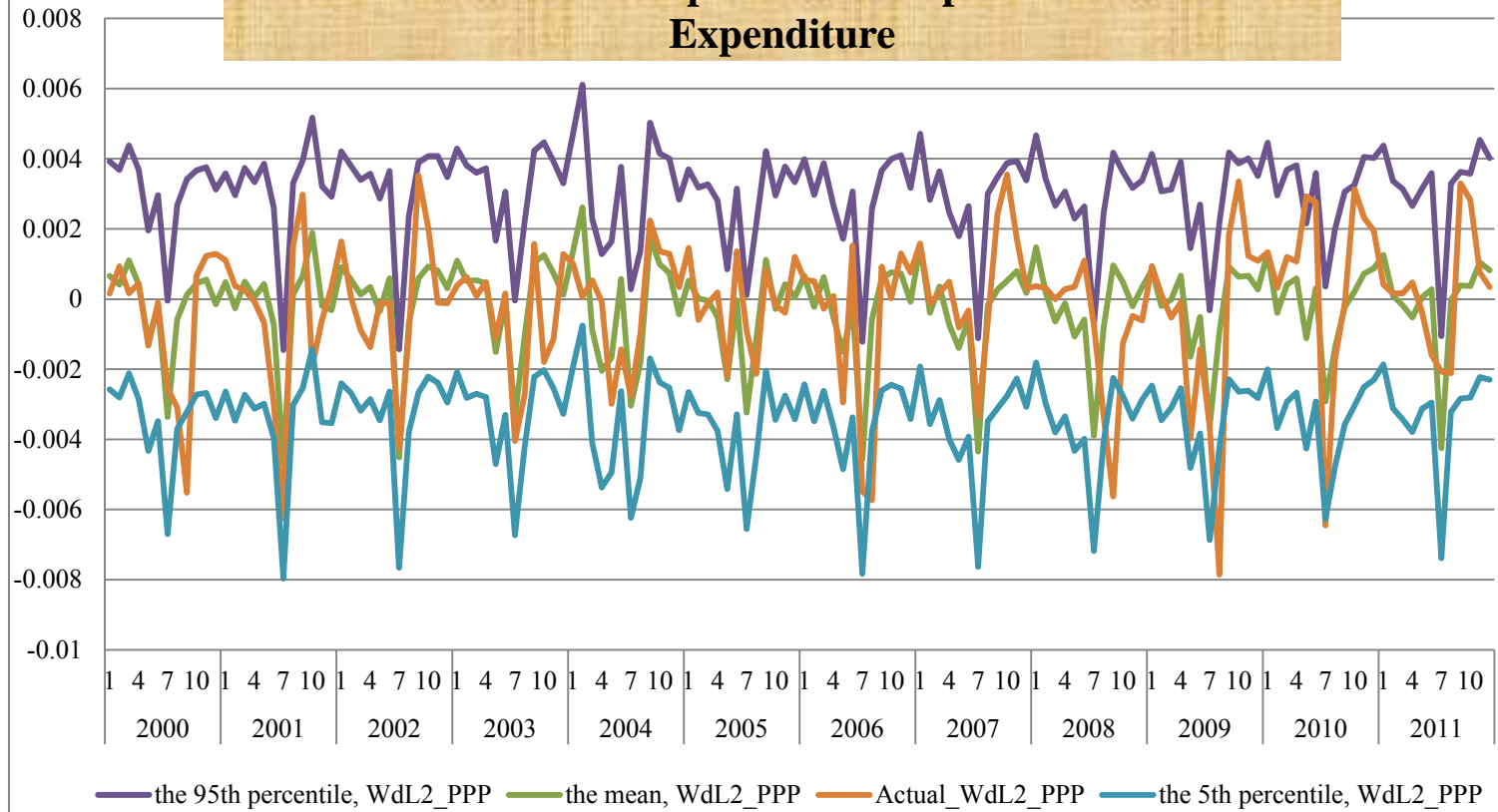
VITA

Maryam Tabarestani was born and raised in Mazandaran, Iran. She completed her bachelor's degree in Pure Economics in Shiraz (Pahlavi) University. She could achieve the first rank student award in Economics department, Shiraz (Pahlavi) University. After completing her bachelor's degree, she started working for the Ministry of Cooperatives in Tehran. At the same time, she began her master degree in economic planning and development. After two years working she attained the first place employee award and got job promotion from economics expert to director of economics research group in the Ministry of Cooperatives. Her master thesis subject was "The Estimation of Productivity of Consumer Cooperatives."

She got her second master degree in Public Management and during this time she was also teaching in Azad University in Tehran, while she was still working for the Ministry of Cooperatives. She accomplished a ten-year economics research and a five-year teaching in economics subject experiences before she and her family move to the United States of America. During this period she got several awards such as the highest second place in economics research on Cooperative Firms, in Iran. She was the representative of the Ministry of Cooperatives in Iranian Productivity Organization which was a member of Asian Productivity Organization. She had also participated in several national and Asian seminars and presented papers. She has several articles (in Farsi) about the economics activities of Cooperative Firms and productivity.

In 2003, she and her family moved to the U.S. and she started her PhD program in agricultural economics, in Department of Agricultural Economics, Louisiana State University, Baton Rouge, Louisiana, in fall 2007. After completing her PhD program, she would be pursuing her research activities, especially about the subject that she worked on as her dissertation.