Three Essays on Price Analysis of Summer Flounder and China's Soybean Imports

Wei Chen

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Daniel B. Taylor, Co-Chair
Daniel E. Kauffman, Co-Chair
Mary A. Marchant
Everett B. Peterson
Andrew Muhammad

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Abstract

This dissertation contains three papers from two projects. The first two papers (Chapter Two and Chapter Three) are from a project entitled "Managing Flounder Openings for Maximum Revenue." The objective of this project is to (1) estimate the monthly dockside price of summer flounder and identify seasonality in this price; and (2) set up a mathematical programming model to maximize the landing revenue by allocating the federal government quota on summer flounder across twelve months.

In the first paper (Chapter Two), various forms of inverse demand equations are used to estimate the dockside price of summer flounder. These models are evaluated based on their out-of-sample forecasting performance. A structural functional form is selected. In the second paper (Chapter Three), the selected price equation for summer flounder is applied into a revenue maximization model with both the federal government quota constraint and biological constraints from twelve months. The model is solved using CONPOT Solver of GAMS 21.5. The results of the scenarios indicate that the industry should move the landing effort from the period of October – February to the period of March – August. Comparing with historical data, this method can increase $44.73 million for the industry of landing summer flounder from 1991 to 2005.

The third paper (Chapter Four) investigates how China's soybean import prices and domestic prices of soybeans and soybean products affect China's soybean imports. Since 2000, soybeans have been the U.S. leading agricultural exports for bulk commodities. China is the largest importer of U.S. soybean exports. For China's soybean crushing industry, imported soybeans are inputs rather than final products and used to produce soybean meal and oil. A differential production model, which is derived from a two-stage profit maximization model in producer theory, is adopted in this research. Estimates are used to calculate conditional and unconditional price elasticities for China's soybean imports from its major source countries – the United States, Argentina, and Brazil. In addition, the Divisia index and unconditional output price elasticities are obtained for China's soybean imports. Estimation results support the hypothesis that China's soybean imports are determined by its domestic demand for soybean meal, rather than soybean oil. This implies that U.S. agribusinesses should pay attention to the dominant role of China's demand for soybean meal and animal feed. U.S. agribusinesses can also use results in this research to evaluate how China's soybean imports from different source countries will change when either international market prices or China's domestic market prices change.

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First I want to thank my wife, Heng Wen, for her tireless support and encouragement over the last five years. I would also need to express my gratitude to committee co-chairs Drs. Dan Taylor and Dan Kauffman, and Dr. Everett Peterson for their guidance and mentoring on my first project about quota management on landing summer flounder. I very appreciate Dr. Mary Marchant for her introducing me into the exciting field of China's agricultural commodity imports. Without her advices and guidance from my English to research, it would be impossible for me to finish this paper. I am also very grateful for Dr. Andrew Muhammad from Mississippi State University for his generous guidance on the method of differential production model. I very appreciate Drs. Fred Gale and Francis Tuan, ERS, USDA for collecting and providing the data of China's soybean imports. I also thank Virginia Sea Grant and NRI, USDA for providing me financial support over the last five years. Last but not least, I would like to thank my family in China for their support. I want to dedicate this work to my son, Proudman Yuheng Chen, as a record of his father's life at Virginia Tech.

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Chapter One

Introduction

This dissertation consists of price analysis for two different projects. The first project discusses the federal quota management on landing summer flounder across Mid-Atlantic States. This project has two stages, which are discussed in Chapter Two and Chapter Three. Chapter Two investigates the seasonality in the monthly dockside price of summer flounder landed across Mid-Atlantic States and proposes an inverse demand function to explain fluctuations of this price. In Chapter Three, this inverse demand function is put into a mathematical programming model to allocate the federal government quota among twelve months to maximize the industry revenue of landing summer flounder.

The second project discusses China's soybean imports from global markets in Chapter Four. In this chapter, a differential production model is set up to investigate how China's soybean import prices and its domestic prices of soybeans and soybean products – soybean meal and oil – affect this country's soybean imports from its three major suppliers – the United States, Argentina and Brazil.

Chapter Two

Estimating the Monthly Dockside Price of Summer Flounder — Stage One of Managing Flounder Openings for Maximum Revenue

2.1. Introduction

The allowable commercial catch of summer flounder (fluke) is set each year by the National Marine Fisheries Service (NMFS) after the agency assesses current stock levels and the future stock level requirements, which are set by Congress. Each flounder catching state is then allocated a percentage of the Total Allowable Landings (TAL). The allocation is based on the percent of total catch each state had historically. It is the state's responsibility to manage the catch so that its percentage of the TAL is not exceeded. Each state allocates its quota amongst the months as best it can. States would like to allocate the quota so as to maximize revenue from the summer flounder catch. They could do this better if there was more information about seasonal summer flounder demand.

The overall purpose of this project (Chapter Two and Chapter Three) is to establish an optimization model, which maximizes annual revenue from the commercial summer flounder catch by better allocating the annual quota among twelve months. In Chapter Two, a dockside inverse demand function to predict flounder price is specified and estimated. This function will be used in Chapter Three to allocate the quota to maximize revenue.

In Chapter Two, two modeling approaches are applied. Both structural and time series models are created to see who has a better forecast performance. The structural model has a flexible functional form and allows for second-order effects such as elasticities or flexibilities of substitution (Greene, 2003 and Berndt and Christensen, 1973). The structural model is static.

Time series models are also used to estimate demand. Different model methods like autoregressive and moving average (ARIMA) and vector autoregression (VAR) methods are applied to estimate the ex-dock price. The model with the best forecast performance is used in the optimization model in Chapter Three.

Section 2.2 discusses the literature review of the two modeling approach. Section 2.3 discusses the data used for modeling. Section 2.4 discusses evaluating forecasting performance. Estimation of the structural and time series model is presented in section 2.5 and 2.6. In section 2.7, a model with the best forecast performance is selected, and then tested to determine if it is statistically adequate. Section 2.8 discusses the economic meaning of the best model. Conclusions are in section 2.9.

2.2. Models for Predicting the Monthly Price of Summer Flounder

2.2.1. Inverse Almost Ideal Demand System (IAIDS) and Structural Model

To estimate the dockside price of summer flounder, two modeling approaches are applied. In the structural model approach, the dockside price of summer flounder is estimated as a function of its quantity and substitute quantities. Every year, the federal government issues a quota for the maximum pounds of fish that can be landed. Thus, the supply of summer flounder is more or less fixed at the beginning of the season. An inverse demand function is estimated. Eales and Unnevehr (1994) propose an inverse almost ideal demand system (IAIDS) to estimate inverse demand function and encompass restrictions proposed by consumer theory. The IAIDS model is derived from a distance function. For a fixed utility level u, given any fixed bundle of commodities q, a distance function, $D(q,u)$, is a solution to the following problem:

(2.1) $D(q,u) = \min_p p \cdot q$

subject to

(2.2) $e(p,u) = 1$,

where $e(p,u)$ is a cost function. The distance function $D(q,u)$ gives the proportional distance along a ray through the origin that quantities must be reduced or increased to reach a particular indifference surface. The distance function is defined implicitly by $U\{q / D(u,q)\} = u$. This is shown in Figure 2.1 of a two-good example. The distance function is dual to the cost function $e(p,u)$, such that :

(2.3) $e(p,u) = \min_q p \cdot q$

subject to

(2.4) $D(q,u) = 1$.

Diewert (1982) discusses properties of the distance function: it is linearly homogeneous, concave, non-decreasing in quantities and decreasing in utility. These properties are based on consumer theory. At the optimum, similar to the cost function, the differentiation of $D(q,u)$ with respect to the quantity of a particular good yields the compensated inverse demand for that good [Deaton (1979, P. 394)]. Based on the properties of the distance function and the compensated inverse demand, Eales and Unnevehr (1994) propose an IAIDS model. This model is a nonlinear equation system:

(2.5) $w_i = \alpha_i + \sum_j \gamma_{ij} \ln q_j + \beta_i \ln Q$

with $\ln Q$ given by

(2.6) $\ln Q = \alpha_0 + \sum_j \alpha_j \ln q_j + 0.5 \sum_i \sum_j \gamma_{ij} \ln q_i \ln q_j$

where w_i is the market share of commodity i, and $w_i = \frac{\partial \ln D(q,u)}{\partial \ln q_i}$, q_i is the demand for commodity i, q_j is demand for commodity j, $\ln Q$ is a quantity index. Based on properties of the distance function, a set of restrictions are imposed on estimation to guarantee the estimated model satisfies consumer theory. The sets of restrictions are

(2.6) Adding-Up $\sum_i \alpha_i = 1$, $\sum_i \gamma_{ij} = 0$, and $\sum_i \beta_i = 0$ (or $\sum_i w_i = 1$) ;

(2.7) Homogeneity $\sum_j \gamma_{ij} = 0$;

(2.8) Symmetry $\gamma_{ij} = \gamma_{ji}$.

Anderson (1980) discusses theoretical properties of inverse demands functions and proposes quantity and scale flexibilities (in the paper, Anderson still uses elasticities). Eales and Unnevehr (1994) discuss how to calculate quantity and scale flexibilities in IAIDS model. Demand for a commodity is said to be inflexible if a 1% increase in consumption of that commodity leads to a less than 1% decrease in the normalized price (price divided by expenditure) of that commodity in consumption. Scale flexibility is the change in the normalized price of the commodity in consumption with 1% increase in expenditure. Anderson (1980) proposes a method on how to derive constant utility or compensated quantity flexibilities in a constant utility or compensated inverse demand functions. For good i, its own compensated quantity flexibility is non-positive and its compensated quantity flexibility to good j is (1) non-positive if good j is a substitute to good i and (2) non-negative if good j is a complement to good i. The IAIDS model has been applied to demand for a number of biologically producer products like fresh tomato demand in the U.S. (Grant and Foster 2005); meat demand (Eales and Unnevehr 1993, Olowolayemo, Martin and Raymond 1993 and Schroeter and Foster 2004); oyster demand in the U.S. (Dedah, Keithly, Diop and Kazmierczak 2007); and Dutch flower auctions (Steen 2006).

In this chapter, a structural model borrows ideas from IAIDS model in the following ways: (1) the variables in this model are all log transformed for calculating the price flexibilities; (2) a second degree Taylor series expansion is applied to include nonlinear terms of explanatory variables; (3) a quantity index is generated to calculate the scale flexibility. The details of the structural model will be further discussed in section five.

However, this structural model is different from the IAIDS model and the structural model is a single equation model. The differences are rooted in the goal of the project. First, the different price models will be evaluated by comparing their forecasting performance. They will be used to forecast out-of-sample monthly price of summer flounder in 2005. The IAIDS model is an equation system, and the price of summer flounder does not exist in the IAIDS model, but it is encompassed in the left hand side market share of summer flounder. In the out-of-sample forecasting, if the monthly landings of summer flounder and its substitutes in 2005 are not considered exogenous, it would be impossible to check the forecasting of the model. However, if the data in 2005 are used to check the forecasting, only the single equation of summer flounder market share is needed. So, in both estimation and forecast performance evaluation, a single equation model of summer flounder rather than the complete IAIDS model will be applied. Secondly, since the IAIDS model is derived from a distance function, the consumption data is required to set up the model. The project's goal is to maximize the industry revenue from the summer flounder catch at the ex-dock level. The data collected for the project are ex-dock quantity and price. They are different from consumption data collected from retailers and supermarkets. Thus, it is not feasible to use the ex-dock data in the IAIDS model, and then a single equation model is applied. The details of the structural model are discussed in section five.

2.2.2 Time Series Models

In the time series model approach, two types of models are estimated: (1) autoregressive integrated moving average (ARIMA) models and (2) vector autoregressive (VAR) models. ARIMA model is a univariate single equation model based on current and past observations of the data and no exogenous variables are included for either estimation or forecast. Thus, different from the structural model, casual structures implied by economic theory are not included. ARIMA models can be used as a benchmark in evaluating the forecasting performance of the structural model for this project. ARIMA models have been widely applied in many fields like forecasting beef prices (Oliveira, O'Connor and Smith 1979), forecasting fertilizer prices (Vroomen 1991), analyzing agricultural commodity markets (Myer and Yanagida 1984, Brandt and Bessler 1984 and Gerlow, Irwin and Liu 1993), forecasting food prices in transitional economies (Olorunnipa and Florowski 1993), forecasting prices in the lamb industry (Vere and Griffith 1995 and Malaty, Toppinen and Vittanen 2007), modeling dairy production (Macciotta, Vappio-Borlino, and Pulina 1999) and modeling fish production (Tsitsika, Marvaelias and Haralabous 2007). The details of ARIMA method used in the project are discussed in section 2.6.

Different from ARIMA model, the vector autoregressive (VAR) model contains two or more variables. But these variables are all endogenous. This method avoids the problem of distinguishing exogenous variables from endogenous ones. VAR models describe relationships among these endogenous variables. But similar to ARIMA models, it is difficult to find a concrete economic theoretical basis for VAR models. Thus, VAR models are used as another benchmark to evaluate the forecasting performance of the structural model. VAR models have been applied in agricultural economics covering topics like forecasting the U.S. cattle prices (Zapata, Hector O. and Philip Garcia 1990), analyzing livestock prices (Miljkovic 2006), forecasting U.S. shelled pecan prices (Ibrahim 2007), and modeling soybean prices (Goodwin, Schnepf and Dohlman 2005). The application of VAR models in the project is discussed in section 2.6.

2.3. Data

This research focuses on the ex-dock revenue, which is the product of the ex-dock price and quantity landed. In estimating an inverse demand function to predict the monthly real price of summer flounder, the authors used data for summer flounder and its substitutes, such as Atlantic, winter, witch, and yellowtail flounder. The value and quantities of these flounders are available at the website of the Office of Science and Technology, National Marine Fisheries Services (NMFS). Based on industry interviews, other potential substitutes are imported fresh and frozen flounder. The monthly imported pounds and values of these commodities are also available from the Office of Science and Technology, NMFS. The price data collected from the above websites are nominal. To estimate demand, the real prices are required. Nominal prices were transformed to their corresponding real ones by using the Consumer Price Index (CPI) from the U.S. Department of Labor. The specific index used was the CPI - All Urban Consumers U.S. all items, 1982-84=100.

The inverse demand functions are estimated by using the data from 1991 to 2004. Then the estimated models are used to forecast the real monthly prices of summer flounder in 2005. The forecasting results are compared with the real monthly price in 2005. The model with the best forecasting performance is used to maximize revenue in the second stage of this research.

2.3.1. Summer Flounder

The monthly landing and real price of summer flounder from January 1991 to December 2005 are contained in Figure 2.1. In the first four years, the monthly landing reaches the highest level in October. In the next eight years, the monthly landing reaches the highest level in January, except for 2000. In 2000 and from 2003 to 2005, the highest landing occurred in February. The lowest landing was distributed in five months. Those months were March 1998 and 2001; April 1993, 2003, and 2004; May 1991, 2002, and 2005; June 1992, 1994, 1995, 1999, and 2000, and December 1996 and 1997. The monthly real price fluctuated seasonally. The highest monthly real price months were March 1994, 1997 to 1999, and 2001; April 1996, 2000, 2003, and 2004; May 2002 and 2005; July from 1991 to 1993; and August 1995. Correspondingly, 13 out of the 15 lowest landing months were in the period from March to August. The lowest monthly real price was distributed in 4 months. It occurred in January from 1995 to 1997 and 1999 to 2001; February 1994, 2002, 2004, and 2005; October 1991 and 1993; and November

1992, 1998, and 2003. These low prices coincided with the highest landings that occur in three months: January, February, and October, as one would expect.

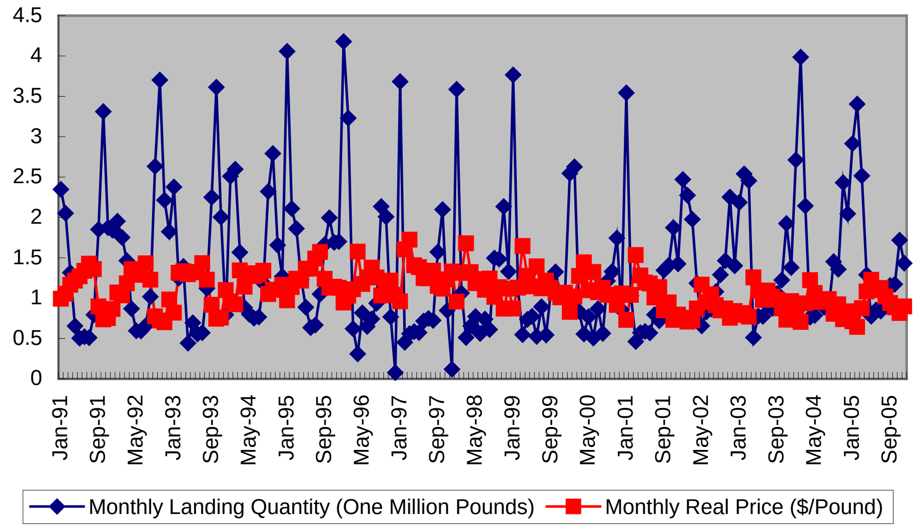

Figure 2.1. Monthly Landing Quantities and Real Prices of Summer Flounder (Source: Office of Science and Technology, National Marine Fisheries Service; Base Year of Price: 1982-1984)

The average and standard deviation of monthly landing of summer flounder in Figure 2.2 for each month across 14 years from 1991 to 2005 show how production cycles. The highest average monthly landings were in January (2.99 million pounds), February (2.10 million pounds) and October (2.02 million pounds). These are the only months that average about two million pounds. In March the average landings drop off to 1.35 million pounds. The five lowest average monthly landings are April through August which all average just under 1 million pounds. In September and October, the average landings started to increased again with 1.64 and 2.02 million pounds respectively. In December, the average landing decreased to 1.24 million pounds. The standard deviation follows the same pattern, where the higher the average was, the higher the standard deviation was, and *vice-versa.* In Figure 2.3, the annual landings from 1991 to 2005 are plotted. The lowest annual landing was 12.68 million pounds in 1997 and the highest was 20.41 million pounds in 2004.

The average and standard deviation of monthly real price for each month across 15 years from 1991 to 2005 are contained in Figure 2.4. The average monthly real prices were slightly above $1.20/pound from March to August. In the other months, the average monthly prices were less than $1.05/pound and the lowest average monthly real price was $0.88/pound in January. The high price months from March to August in Figure 2.4 matched the low landing months from April to August indicated in Figure 2.2.

Some industry participants argue that in Mid-January, summer flounder prices start to move up from a late fall low. The monthly real price data from 1991 to 2005 plotted in Figure 2.4 shows that from March to August the average monthly real price was stable and decreased in September, October and November. A moderate increase happened in December, followed by another decrease in January. Then the price increased and returned back to high levels beginning in March. The goal of the price estimation in the first stage of this research is to describe the seasonality in the monthly real price.

Comparing Figure 2.2 with 2.4, it is not difficult to observe that the ratio of average to standard deviation was higher for the monthly landings than for the monthly prices. It means that the monthly prices of each month from 1991 to 2005 were more stable than the corresponding landings. The monthly landings of summer flounder are determined largely by quota allocation but also by other factors like weather and fish movement. Ocean quota is not generally opened in times of the year when flounder are difficult caught in the ocean.

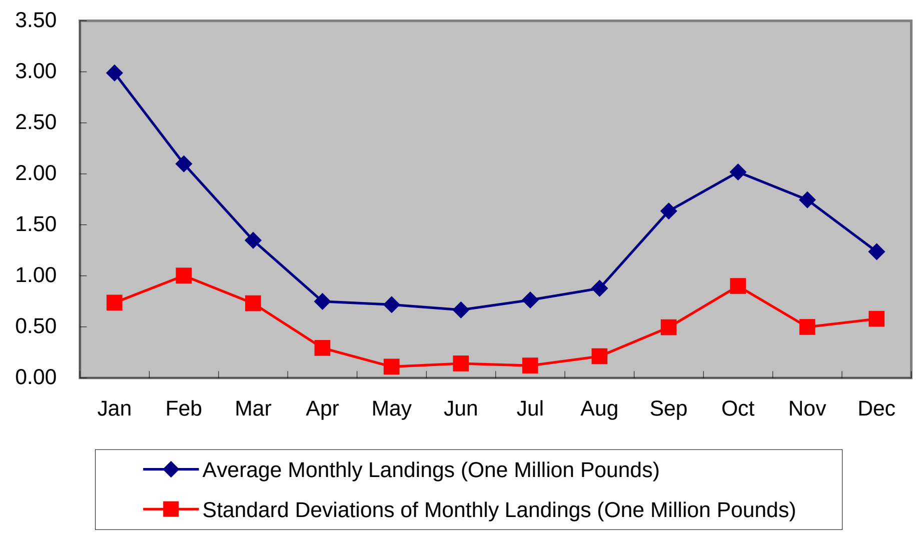

Figure 2.2. Averages and Standard Deviations of Monthly Summer Flounder Landings from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

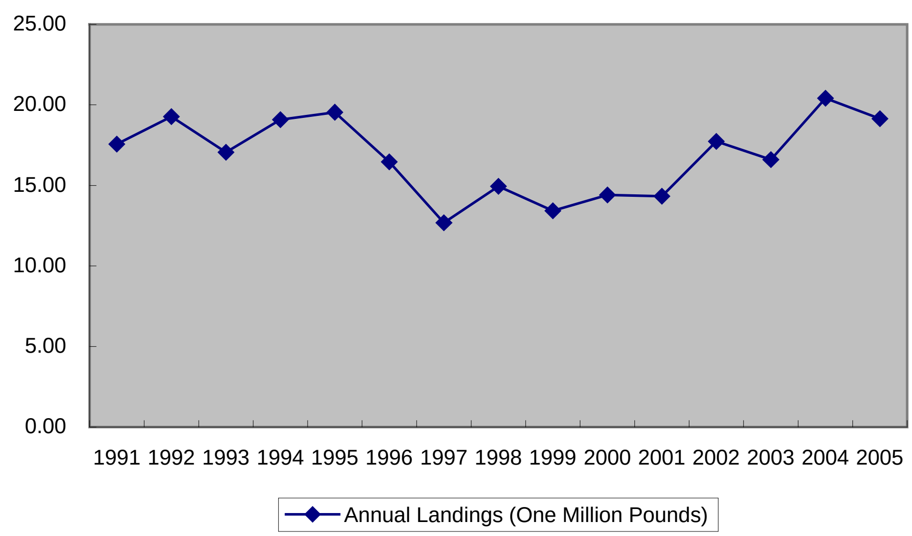

Figure 2.3. Annual Landings of Summer Flounder from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

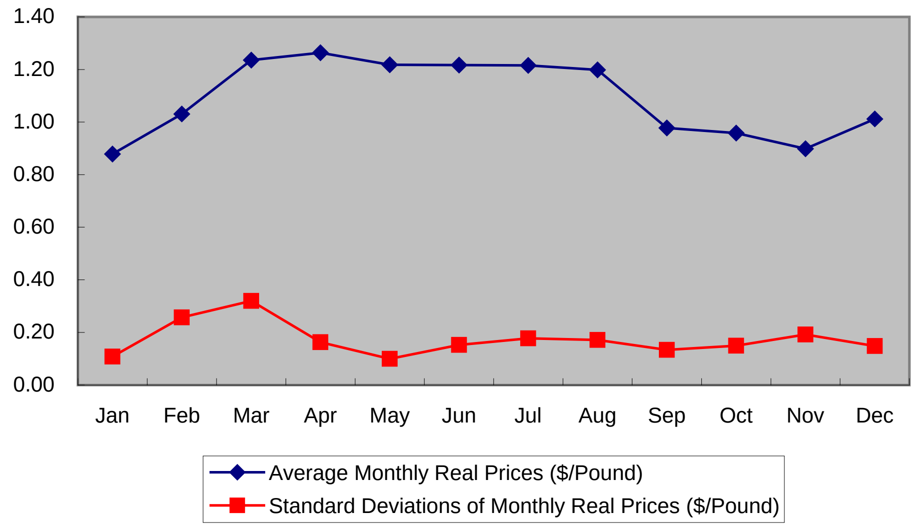

Figure 2.4. Averages and Standard Deviations of Summer Flounder Monthly Real Prices for Each Month from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service; Base Year of Price: 1982-1984)

2.3.2. Substitutes

The author collected 180 observations of the monthly price and landing of summer flounder across 1991 to 2005. Since the last year's 12 observations are to be used in an out-of-sample forecasting to evaluate performances of competing models, there are 168 observations that can be used in the estimation. A single equation structural model is one of the potential models. In the single equation structural model, the monthly real price of summer flounder is a function of its landing quantity, substitutes' landing quantities, a quantity index and a series of dummy variables. The nonlinearity of the model structure is approximated by a second-order Taylor series expansion. There are 11 monthly dummy variables for monthly effects, and 13 annual dummy variables for annual effects in the model. So, there are 24 dummy variables. A quantity index is introduced to estimate scale flexibility. If the number of substitutes is K, then, including summer flounder quantity and the quantity index, there will be $(K+2)$ first-degree variables and

$\left[(K+2)+(K+1)+......+1\right]=\frac{(K+3)(K+2)}{2}$ second-degree variables. In estimating a full structural model, the Taylor series expansion is applied to include second-degree variables. Counting dummy variables, first-degree variables, second-degree variables and one intercept, the total number of variables estimated is

$$1+24+(K+2)+\frac{(K+3)(K+2)}{2}=25+\frac{(K+5)(K+2)}{2}.$$

With the number of observations available for the estimation at 168, the number of substitutes will be limited to no more than 4, so the variables will be less than 52 in a full model. Imported fresh and frozen flounder are other possible substitutes for summer flounder. These imports will be discussed in the next section.

Table 2.1. Total Landing and Value Percentages of Ten Subspecies of Flounders

	Atlantic	Righteye	Sand Dab	Starry	Southern	Summer	Windowpane	Winter	Witch	Yellowtail
Total Landing Percentage	12.93%	9.56%	2.36%	1.03%	5.73%	25.09%	2.55%	17.12%	8.03%	15.62%
Total Value Percentage	12.64%	0.54%	0.70%	0.22%	8.00%	34.69%	1.19%	17.30%	9.95%	14.78%

Source: Office of Science and Technology, National Marine Fisheries Service

Including summer flounder, the website of the Office of Science and Technology from NMFS contains information of fourteen subspecies of flounder, Atlantic plaice, arrow tooth, four spots, Pacific sand dab, Pacific sand dab (long fin), Pacific sand dab (speckle), right eye, southern, starry, summer, windowpane, winter, witch, and yellowtail. Around 40% of the landings of arrow tooth flounder cannot be linked to specific months. So, the arrow tooth data cannot be used. The landing data of four spots, Pacific sand dab (long fin) and Pacific sand dab (speckle) are not available. So, there are nine candidate substitutes, three out of which, Atlantic, winter, and yellow tail flounders, are picked. These three substitutes are the top three in both landing and value among the 9 candidates.

Table 2.1 contains the 10 subspecies' percentages of the total landing (in pounds) and market value (in dollars) of all flounders from 1991 to 2005. Including summer flounder, the four subspecies, Atlantic, summer, winter, and yellowtail flounder, represent 70% of the total landings and 80% of the total value.

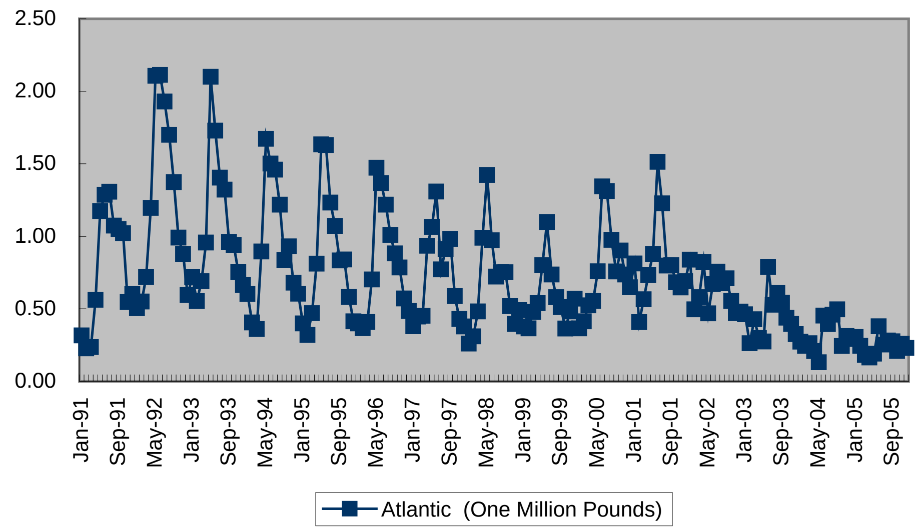

Figure 2.5. Monthly Landings of Atlantic Flounders from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

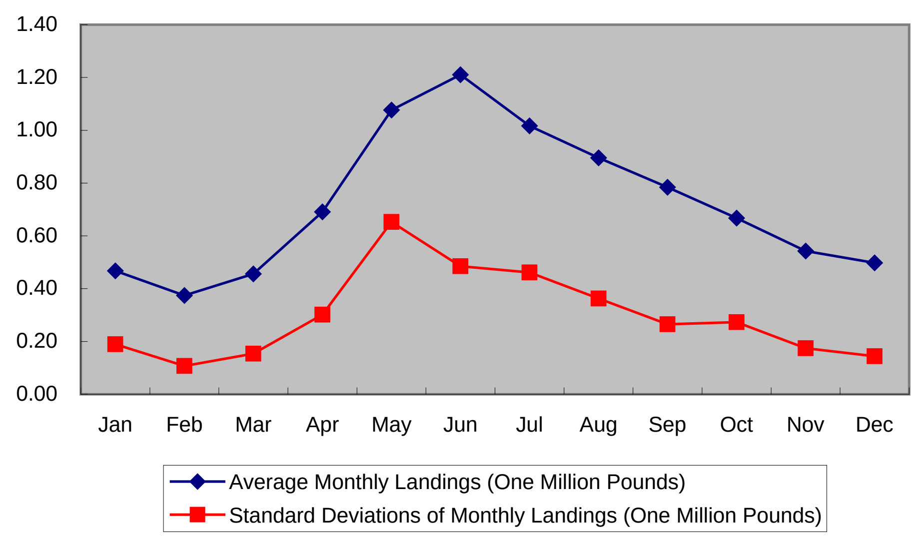

Figure 2.6. Averages and Standard Deviations of Atlantic Flounder Monthly Landings for Each Month from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

The monthly landing of Atlantic flounder is contained in Figure 2.5. It began to decrease in 2001. As shown in Figure 2.6, average monthly landings of Atlantic flounder reached their highest level in June and then an eight-month straight decrease began in July and ends in February. The average monthly landing was at the lowest level (0.37 million pounds) in February. Recall from Figures 2.2 and 2.4 that June was the month when the average monthly landing of summer flounder was at its low but the average monthly price was at its high. The ratio of average landings to their standard deviation reached the highest level in June. In the months before or after June, the ratio was relatively stable. In Figure 2.7, the annual landing of Atlantic flounder began to decrease in 1993 after a jump in 1992. The annual landing temporarily increased in 2000 and 2001, followed by a four-year decrease.

The monthly landings of winter flounder are contained in Figure 2.8. The winter flounder average monthly landing reached the highest level in June at 1.42 million pounds and then began to decrease until February to a level of 0.28 million pounds (Figure 2.9). However, different from Atlantic flounder, the standard deviation of winter flounder's monthly landings was very stable. The ratio of average landings to standard deviation was high from May to December. In 1991 and 2001, the annual landings were high and reached 15.63 and 15.28 million pounds respectively (Figure 2.10). In 1994 and 2005, they fell to 7.64 and 8.08 million pounds.

The monthly landings of yellowtail flounder had an increase in 2000 (Figure 2.11). The average monthly landings of yellowtail flounder are plotted in Figure 2.12. The lowest catch occurred in September at 0.47 million pounds and the highest occurred in December at 1.14 million pounds. The ratio of average to standard deviation was very low in July and August, but much higher in other months. Annual landings fell to 4.25 million pounds in 1995 from 16.84 million pounds in 1991. Then a six-year increase brought the annual landing to 16.07 million pounds in 2001. It decreased to 9.08 million pounds in 2005 (Figure 2.13).

As previously noted, the average monthly real prices of summer flounder stayed at a high level from March to August. Correspondingly, the average monthly landings of summer flounder were at low levels from April to August. However, the fluctuation in the average monthly real prices of summer flounder is very small compared to the landings. Figure 2.14 displays average monthly real prices and landings of summer flounder and average monthly landings of its substitutes. It can be observed that when the summer flounder landings were low, the average monthly landings of Atlantic, winter, and yellowtail flounders were at high levels. Atlantic and winter flounder had the highest landings in June and yellowtail flounder had the highest landing in May. This pattern of landings could be one reason why the summer flounder monthly real price didn’t increase as much as one would expect during the summer given its low catch level.

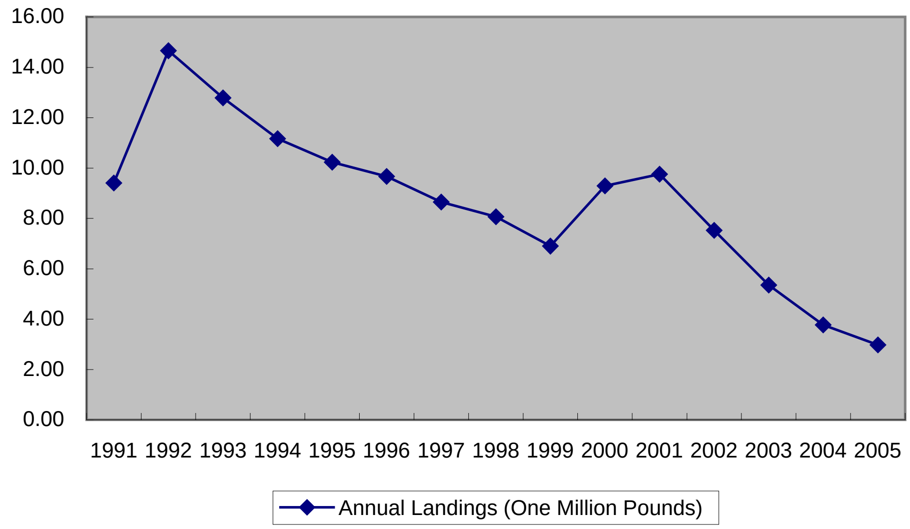

Figure 2.7. Annual Landings of Atlantic Flounder from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

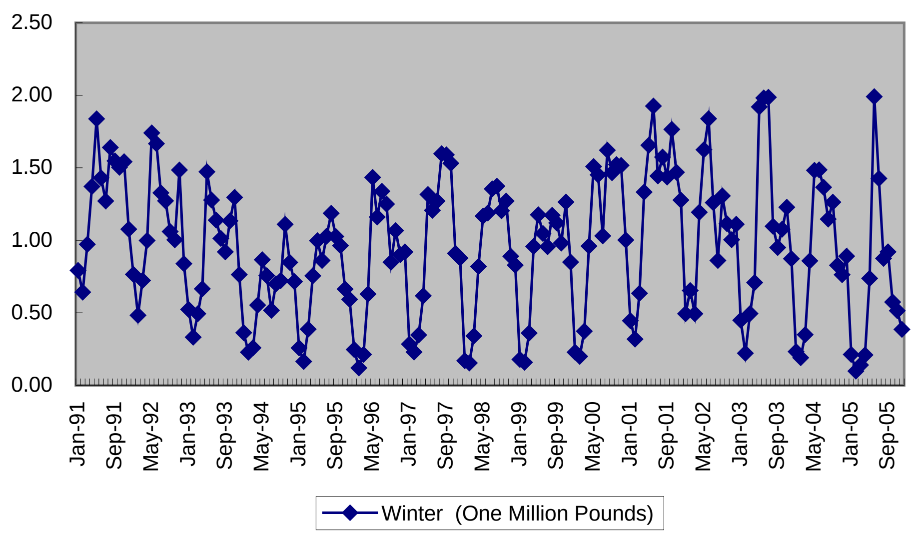

Figure 2.8. Monthly Landings of Winter Flounders from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

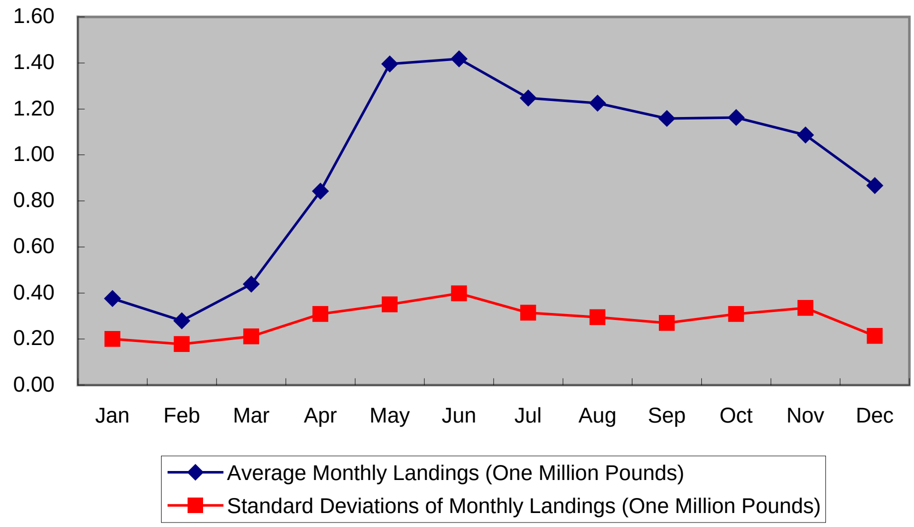

Figure 2.9. Averages and Standard Deviations of Monthly Winter Flounder Landings from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

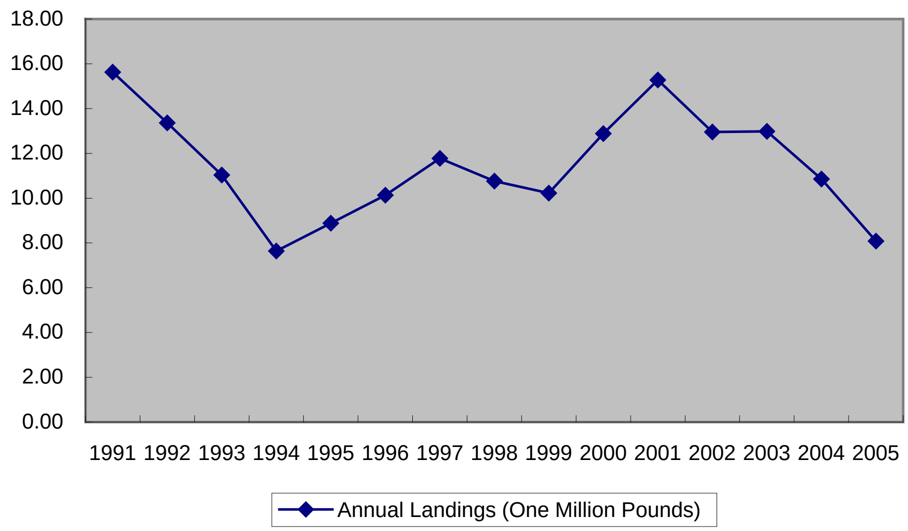

Figure 2.10. Annual Landings of Winter Flounder from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

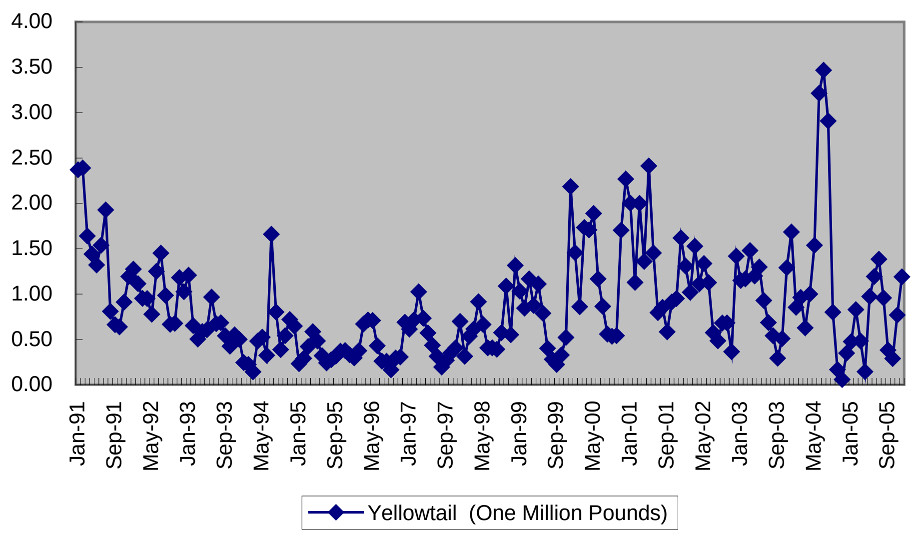

Figure 2.11. Monthly Landings of Yellowtail Flounders from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

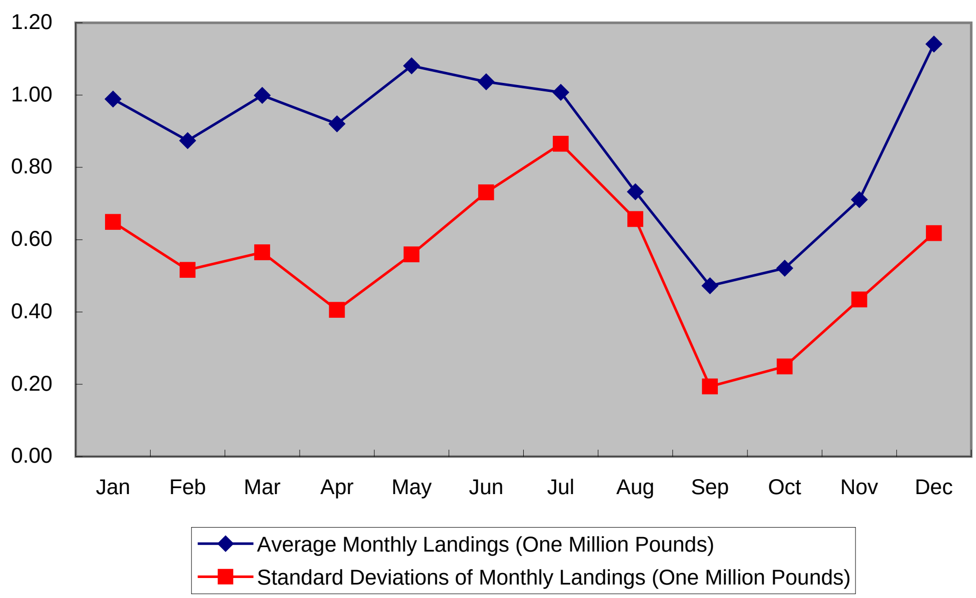

Figure 2.12. Averages and Standard Deviations of Monthly Yellowtail Flounder Landings from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

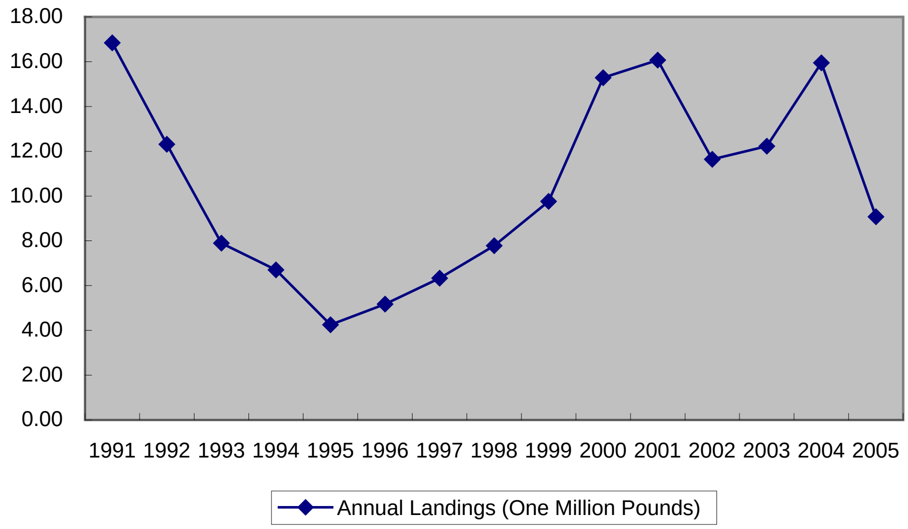

Figure 2.13. Annual Landings of Yellowtail Flounder from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

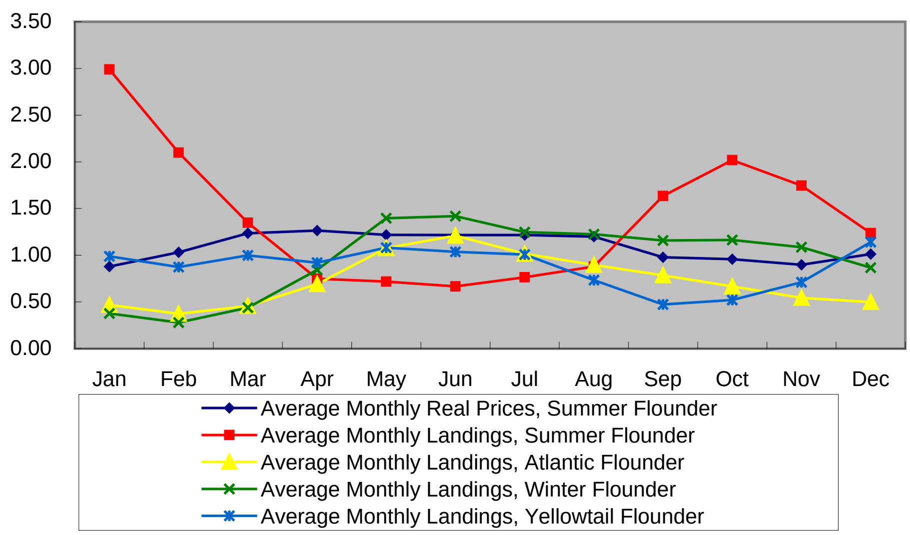

Figure 2.14. Average Monthly Real Prices and Landings of Summer Flounder and Average Monthly Landings of Its Substitutes (Source: Office of Science and Technology, National Marine Fisheries Service)

2.3.3. Imports

From 1991 to 2005, the U.S. imported more than 20 million pounds flounder every year. In the NMFS database, imports consisted of two groups: fresh flounder and frozen flounder. For each group, the import isn't categorized into different subspecies of flounder. So, the two groups, fresh flounder and frozen flounder, are considered as two substitutes for summer flounder. The monthly imports of the fresh and frozen flounder from 1991 to 2005 are contained in Figure 2.15.

Fresh flounder imports were the highest in September (Figure 2.16). They fell to a low in winter and spring from November to April. The standard deviation followed a similar fluctuating pattern as that of the average. It was the highest in August and September, but didn't increase as much as the average did. The annual imports of fresh flounder reached their highest level in 2003 followed a sharp decrease in 2004 (Figure 2.17).

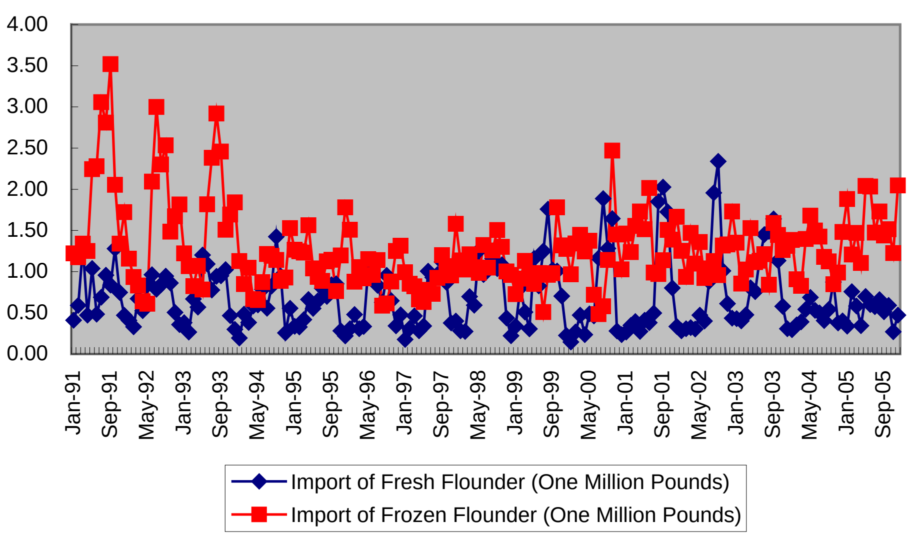

Figure 2.15. Monthly Imports of Fresh and Frozen Flounders from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

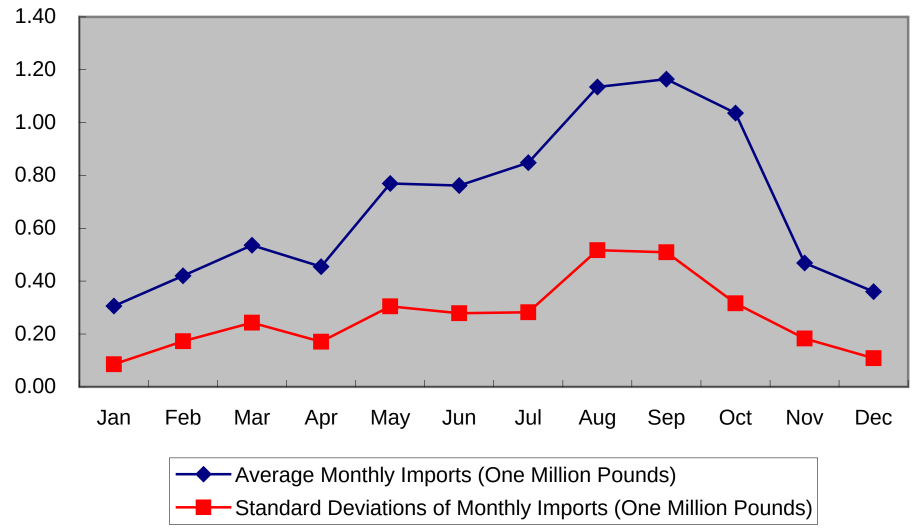

Figure 2.16. Averages and Standard Deviations of Monthly Imports of Fresh Flounder from1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

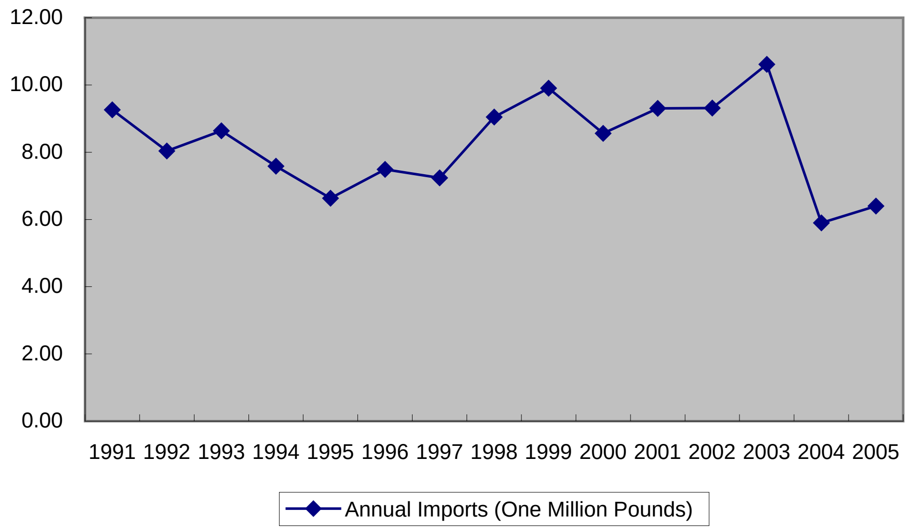

Figure 2.17. Annual Imports of Fresh Flounder from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

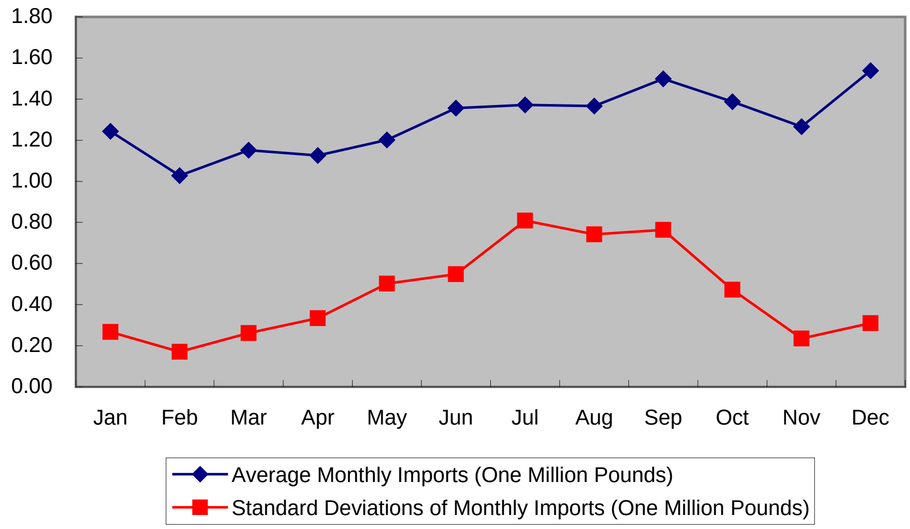

Figure 2.18. Averages and Standard Deviations of Monthly Imports of Frozen Flounder from 1991 to 2005.

The average monthly imports of frozen flounder are plotted in Figure 2.18. The average monthly imports increased gradually from January to December. The standard deviation fluctuated more than the average. In 1991, the annual import of frozen flounder was 24.00 million pounds (Figure 2.19). It fell to 11.19 million pounds in 1997 and increased back to 19.16 million pounds in 2005.

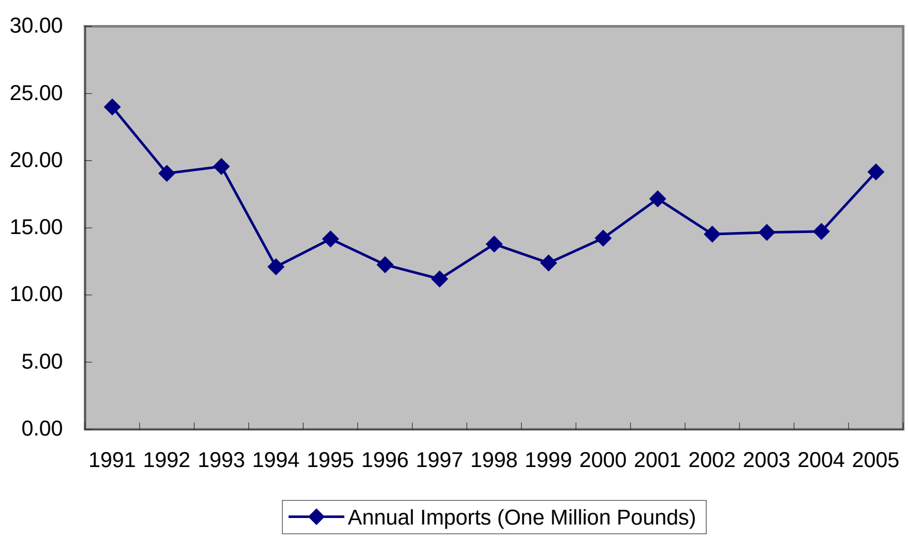

Figure 2.19. Annual Imports of Frozen Flounder from 1991 to 2005 (Source: Office of Science and Technology, National Marine Fisheries Service)

2.4. Tools for Evaluating Forecasting Performance

Both structural and time series models are for estimating the inverse demand function for summer flounder. Many different models are estimated for both approaches. Each of these models forecasts monthly real prices of summer flounder in 2005. To pick the best model in each approach, three statistics measuring forecasting error are calculated and numbers for missing turns are counted for each model.

The statistics measuring forecasting error are Root Mean Squared Error (RMSE), Mean Absolute Percentage Error (MAPE) and Theil Inequality Coefficient (TIC). RMSE measures the average magnitude of the error in a set of forecasts and gives a relatively high weight to large errors. The range of RMSE is from 0 to infinity. The closer to 0, the more acceptable the forecast is. RMSE is a scale dependent measurement. MAPE measures deviation as percentage of actual data. The lower the MAPE is, the more accurate the forecast. TIC is a measure of the degree to which the forecast differs from the realized value. It normalizes RMSE by dividing by the volatility of the forecast and actual values. The range of TIC is from 0 to 1 and zero indicates a perfect fit. MAPE and TIC are both scale independent measurements (No. and Salassi 2006). The equations for computing these three statistics are

(2.9) $RMSE = \sqrt{\sum_{t=1}^{T} u_t^2 \Big/ T}$,

(2.10) $MAPE = \left| \sum_{t=1}^{T} 100 \times \frac{u_t}{A_t} \right| \Big/ T$,

and

(2.11) $TIC = \dfrac{\sqrt{\sum_{t=1}^{T} u_t^2 \Big/ T}}{\sqrt{\sum_{t=1}^{T} A_t^2 \Big/ T} + \sqrt{\sum_{t=1}^{T} P_t^2 \Big/ T}}$,

where u_t is the forecast error and that is equal to actual price, A_t, minus predicted price, P_t.

A predicted price is called a missing turn if it is higher (lower) than the previous predicted price, but its corresponding actual price is lower (higher) than the previous actual price. The fewer the missing turns there are, the better the forecasting is. For structural model and time series approaches, the best forecasting models are determined by applying these criteria in section six and seven. After selecting the best forecasting model from each approach, these best ones are compared again using the above three statistics and the number of missing turns to determine the final model with the best forecasting among all the candidates in both approaches.

In section seven, after a best final model is selected, a series of regressions on u_t will run to evaluate if the forecasting of the final best model is optimal. A forecast is optimal if it is unbiased and efficient (Diebold and Lopez, 1998). To test unbiasedness, a regression is estimated, where

(2.12) $u_t = \alpha + \varepsilon_t$,

where α is an intercept and ε_t is an independent and identically distributed (i.i.d.) error term with mean zero. A forecast is defined as unbiased if the null hypothesis of $\alpha = 0$ is not rejected. This test is a two-tailed t-test. As to efficiency of forecast, Sanders and Manfredo (2003) proposed two regressions of u_t. The two regressions are

(2.13) $u_t = \beta_1 + \delta P_t + \varepsilon_t$,

and

(2.14) $u_t = \beta_2 + \gamma u_{t-1} + \varepsilon_t$,

In Equation (2.13), β_1 is an intercept, P_t is the real price and ε_t is an independent and identically distributed (i.i.d.) error term with mean zero. In Equation (2.14), β_2 is an intercept, u_{t-1} is the forecast error from the previous period and ε_t is an i.i.d. error term with mean zero. The efficiency is defined as neither of $\delta = 0$ (delta efficiency test) nor $\gamma = 0$ (gamma efficiency test) is rejected. Besides optimality, a good forecast should not improve or worsen over time (Sanders and Manfredo, 2003). To test for the stability of the forecast with respect to time, a regression is estimated, where:

(2.15) $|u_t| = \theta_1 + \theta_2 t + \varepsilon_t$.

The term $|u_t|$ is the absolute value of the forecast error. θ_1 is an intercept, t is the trend and ε_t is an i.i.d. error term with mean zero. A hypothesis $\theta_2 = 0$ will be tested. Rejection of this hypothesis would suggest forecasts either improved or worsened over time. Lastly, the diagnostic tests are calculated to check if the estimation is statistically adequate in section seven.

2.5. Structural Model Approach

In the structural model approach, an inverse demand function is estimated. The approach posits that the price of summer flounder is a function of the landings of summer flounder, landings of other flounder species, such as Atlantic, winter, yellowtail and imports of fresh and frozen flounder. In order to get own or cross-price flexibility between summer flounder and its substitutes, a translog function is estimated, where all endogenous and exogenous variables are transformed through a natural log operator. The own-price flexibility measures the percent change in the summer flounder ex-dock price with one percent change in its landing quantity. The cross-price flexibility measures the percent change in the summer flounder ex-dock price with one percent change in its substitutes' landing quantities. A quantity index is introduced into estimation and it gives a scale flexibility, which indicates the percent change in the summer flounder landing price with one percent change in total quantity. Effects of seasonality are estimated by adding monthly dummy variables to the model. Similarly, the annual effect is studied by adding annual dummy variables to the model. The equation is given as

(2.16) $lfsp = f\left(M_i, Y_j, lfsq, lfaq, lfwq, lfyq, lfeq, lfoq, QI\right)$

where: M_i are monthly dummy variables, $i \in I = \{2,3,...,12\}$; Y_j are annual dummy variables, $j \in J = \{92,93,...,04\}$; $lfsp$ is the logarithm of monthly real prices of summer flounder, $lfsq$ is the logarithm of monthly landing quantities of summer flounder, $lfaq$ is the logarithm of monthly landing quantities of Atlantic flounder, $lfwq$ is the logarithm of monthly landing quantities of winter flounder, $lfyq$ is the logarithm of monthly landing quantities of yellowtail flounder, $lfeq$ is the logarithm of monthly imports of fresh flounder, $lfoq$ is the logarithm of monthly imports of frozen flounder, and QI is the quantity index. The quantity index is computed by the following equation

(2.17) $QI = lfsq \times w_{fs} + lfaq \times w_{fa} + lfwq \times w_{fw} + lfyq \times w_{fy} + lfeq \times w_{fe} + lfoq \times w_{fo}$

where $w_i = \dfrac{m_i}{\sum_{i \in I} m_i}$, $i \in I = \{fs, fa, fw, fy, fe, fo\}$, and m_i is the monthly ex-dock value and import value in dollars of landed and imported fish. In Equation (2.17), the subscript fs represents summer flounder, fa represents Atlantic flounder, fw represents winter flounder, fy represents yellowtail flounder, fe represents imported fresh flounder, and fo represents imported frozen flounder.

Since the structural model $lfsp = f(\bullet)$ might be nonlinear, a second degree Taylor series expansion is used to approximate the nonlinearity of the function. The complete form is written in equation (2.18).

$$
\begin{aligned}
(2.18)\quad lfsp = {} & \alpha_0 + \beta_2 M_2 + \beta_3 M_3 + \beta_4 M_4 + \beta_5 M_5 + \beta_6 M_6 + \beta_7 M_7 + \beta_8 M_8 + \beta_9 M_9 + \beta_{10} M_{10} \\
& + \beta_{11} M_{11} + \beta_{12} M_{12} + \gamma_{92} Y_{92} + \gamma_{93} Y_{93} + \gamma_{94} Y_{94} + \gamma_{95} Y_{95} + \gamma_{96} Y_{96} + \gamma_{97} Y_{97} + \gamma_{98} Y_{98} \\
& + \gamma_{99} Y_{99} + \gamma_{00} Y_{00} + \gamma_{01} Y_{01} + \gamma_{02} Y_{02} + \gamma_{03} Y_{03} + \gamma_{04} Y_{04} + \xi_1 \times lfsq + \xi_2 \times lfaq + \xi_3 \times lfwq \\
& + \xi_4 \times lfyq + \xi_5 \times lfeq + \xi_6 \times lfoq + \xi_7 \times QI \\
& + \frac{1}{2}\Big(\delta'_{11} \times (lfsq)^2 + \delta'_{12} \times lfsq \times lfaq + \delta'_{13} \times lfsq \times lfwq + \delta'_{14} \times lfsq \times lfyq + \delta'_{15} \times lfsq \times lfeq \\
& \quad + \delta'_{16} \times lfsq \times lfoq + \delta'_{17} \times lfsq \times QI \\
& \quad + \delta'_{22} \times (lfaq)^2 + \delta'_{23} \times lfaq \times lfwq + \delta'_{24} \times lfaq \times lfyq + \delta'_{25} \times lfaq \times lfeq + \delta'_{26} \times lfaq \times lfoq \\
& \quad + \delta'_{27} \times lfaq \times QI \\
& \quad + \delta'_{33} \times (lfwq)^2 + \delta'_{34} \times lfwq \times lfyq + \delta'_{35} \times lfwq \times lfeq + \delta'_{36} \times lfwq \times lfoq + \delta'_{37} \times lfwq \times QI \\
& \quad + \delta'_{44} \times (lfyq)^2 + \delta'_{45} \times lfyq \times lfeq + \delta'_{46} \times lfyq \times lfoq + \delta'_{47} \times lfyq \times QI \\
& \quad + \delta'_{55} \times (lfeq)^2 + \delta'_{56} \times lfeq \times lfoq + \delta'_{57} \times lfeq \times QI \\
& \quad + \delta'_{66} \times (lfoq)^2 + \delta'_{67} \times lfoq \times QI \\
& \quad + \delta'_{77} (QI)^2 \Big)
\end{aligned}
$$

In examining the full model with all possible substitutes included, multicollinearity is detected. In order to find combinations of explanatory variables that are not multicollinear, a condition number method is applied. To a matrix X, the condition number of $X'X$ is the ratio of the square root of the largest characteristic root of $X'X$ to the smallest. If the condition number is greater than 20, then the multicollinearity problem is serious. After scanning the condition numbers of all combinations of explanatory variables, there are five combinations without multicollinearity problem. These five combinations of variables and their condition numbers are contained in Table 2.2. The five variable groups are sequentially put into the structural model to estimate the monthly real price of summer flounder.

Table 2.2. Condition Number of Different Variables of Structural Model Approach

Variable Group	Condition Number
lfsq, lfaq, lfwq, lfyq	4.06
lfsq, lfaq, lfwq, lfoq	2.93
lfsq, lfaq, lfyq, lfeq	4.21
lfsq, lfaq, lfwq, lfyq, lfeq	4.22
lfsq, lfaq, lfwq, lfeq, lfoq	3.54

In estimation of the models with variables from group one to five, monthly data from January 1991 to December 2004 are used. The monthly real prices in 2005 are then forecasted by using the model estimates with each group of variables. The forecast for 2005 monthly real prices of summer flounder of all the five groups are contained in Table 2.3. The plots of these forecasts are contained in Figures 2.20 and 2.21. Groups 1, 2 and 5 have one missing turn in October, less than other groups. Three statistics, RMSE, MAPE, and TIC, are calculated to evaluate the different group forecasts. They are contained in Table 2.3. The Group Two’s forecast has the smallest values for all the three statistics. The original full model of Group Two have forty-five estimates. Many of them are not significant and need to be removed. In order to avoid removing too many estimates with some really significant variables, the significance level is set at 15%. The original full model of Group Two has forty-five variables. In order to make the model easier to use, the parameter, whose estimates are not significant, are removed. In the original model, any variables whose parameter estimates have $p-$values higher than 15% were removed and the model was estimated again. The process to remove variables whose coefficients had $p-$values higher than 15% three times and the coefficients of all the variables left in the model had $p-$values less than 5%. These variables and their coefficients are labeled as the Final Model in Table 2.4 and the estimated Final Model are listed in equation (2.19).

Table 2.3. Predictions of Real Monthly Price of Summer Flounder in 2005, Group One to Group Five, Structural Model

Date	Real Price	Group One	Group Two	Group Three	Group Four	Group Five
Jan	0.71	0.82	0.74	0.91	0.83	0.86
Feb	0.64	0.80	0.75	0.83	0.83	0.84
Mar	0.87	0.91	0.85	0.99	0.94	0.99
Apr	1.08	0.96	0.98	1.13	0.97	1.03
May	1.23	1.11	1.24	1.16	1.13	1.21
Jun	1.10	1.03	1.06	1.05	1.03	1.00
Jul	1.12	1.11	1.08	1.16	1.11	1.07
Aug	1.02	1.04	1.04	1.14	1.11	1.01
Sep	0.94	0.97	1.00	1.15	1.02	0.99
Oct	0.88	1.00	1.04	1.15	1.05	1.04
Nov	0.81	0.80	0.78	0.89	0.82	0.82
Dec	0.90	0.92	0.92	0.98	0.94	1.02
RMSE		0.0072	0.0046	0.0204	0.0105	0.0108
MAPE		7.880	6.068	14.354	10.182	10.152
TIC		0.0626	0.0503	0.1056	0.0758	0.0768
Missing Turns		1	1	2	2	1

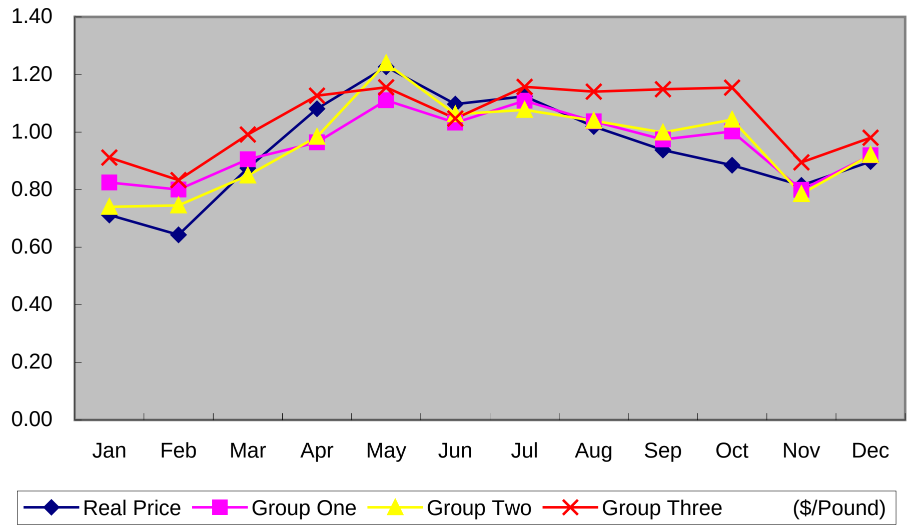

Figure 2.20. Predictions of Real Monthly Price of Summer Flounder in 2005, Group One to Three in Structural Model, and the Actual Historical Prices with Log Transformed Data.

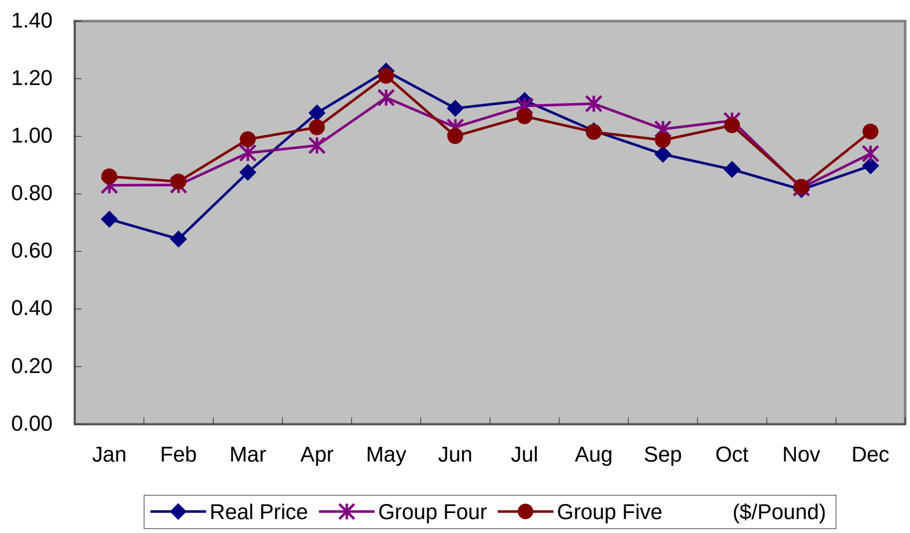

Figure 2.21. Predictions of Real Monthly Price of Summer Flounder in 2005, Group Four to Five in Structural Model, and the Actual Historical Prices with Log Transformed Data.

Table 2.4. Parameter Estimates for Fluke and Summer Flounder Price Forecasting Model

	Full Model			Final Model	
Variable	Estimate	*p*-value	Variable	Estimate	*p*-value
Intercept	0.12039	0.0374	Intercept	0.141867	<.0001
Monthly Binary			*Monthly Binary*		
February	0.03858	0.289	March	0.060426	0.0081
March	0.07623	0.043	November	-0.11625	<.0001
April	-0.016	0.758	December	-0.05824	0.0162
May	-0.057	0.381	*Yearly Binary*		
June	-0.0816	0.221	1994	0.085059	0.0005
July	-0.0524	0.393	1995	0.159146	<.0001
August	-0.0019	0.975	1997	0.098475	<.0001
September	-0.0207	0.694	2001	-0.13164	<.0001
October	-0.0014	0.978	2002	-0.20382	<.0001
November	-0.1191	0.014	2003	-0.16895	<.0001
December	-0.0676	0.147	2004	-0.17652	<.0001
Yearly Binary			*lfsq*	-0.24208	<.0001
1992	0.06077	0.117	$lfsq^2$	-0.1081	<.0001
1993	0.05607	0.162	*lfsq*lfaq*	-0.12919	<.0001
1994	0.16051	0.001	*lfsq*lfoq*	-0.28858	<.0001
1995	0.21179	<.0001	*lfsq*QI*	0.291496	<.0001
1996	0.07923	0.077	*lfaq*lfoq*	-0.19049	0.0001
1997	0.14583	6E-04	*lfaq*QI*	0.266235	0.0003
1998	0.0614	0.137			
1999	0.02537	0.552			
2000	0.01021	0.803			
2001	-0.0963	0.014			
2002	-0.1596	<.0001			
2003	-0.1351	6E-04			
2004	-0.1484	6E-04			
lfsq	-0.2046	0.015			
lfaq	0.03299	0.608			
lfwq	0.09505	0.124			
lfoq	0.05856	0.553			
QI	-0.2788	0.293			
$lfsq^2$	-0.1128	0.007			
*lfsq*lfaq*	-0.158	0.011			
*lfsq*lfwq*	-0.0527	0.511			
*lfsq*lfoq*	-0.4423	2E-04			
*lfsq*QI*	0.40701	0.042			
$lfaq^2$	0.03243	0.299			
*lfaq*lfwq*	-0.0094	0.839			
*lfaq*lfoq*	-0.2262	0.017			
*lfaq*QI*	0.30735	0.043			
$lfwq^2$	0.01143	0.728			
*lfwq*lfoq*	-0.0726	0.365			
*lfwq*QI*	-0.0582	0.684			
$lfoq^2$	-0.0546	0.648			
*lfoq*QI*	0.35403	0.19			
QI^2	-0.0534	0.846			

$$(2.19)\quad lfsp = 0.141867 + 0.060426M_3 - 0.11625M_{11} - 0.05824M_{12} + 0.085059Y_{94} + 0.159146Y_{95} + 0.098475Y_{97} - 0.13164Y_{01} - 0.20382Y_{02} - 0.16895Y_{03} - 0.17652Y_{04} - 0.24208 \times lfsq - 0.1081 \times (lfsq)^2 - 0.12919 \times lfsq \times lfaq - 0.28858 \times lfsq \times lfoq + 0.291496 \times lfsq \times QI - 0.19049 \times lfaq \times lfoq + 0.266235 \times lfaq \times QI$$

2.6. Time Series Model Approach

2.6.1. ARIMA Model Approach

An exogenous variable is not required when an ARIMA model is estimated. The underlying assumption of the ARIMA model is that univariate time series data contain enough information to estimate the model without reference to other variables. As discussed below, before estimating an ARIMA model, possible model structures need to be assessed. It must be determined whether the time series is stationary or non-stationary, and what the autoregressive and moving average orders are.

Because $t-$ tests are appropriate for stationary time series, but inappropriate for nonstationary time series, it is necessary to judge whether a series is stationary or nonstationary before any reasonable estimation and statistical inference can be made. A stationary series will converge to an unconditional mean of the series, but a nonstationary series will not. Normally, a stationary series: (1) fluctuates around a constant long-run mean; (2) has a finite variance that is time-invariant; and (3) has a theoretical autocorrelation that diminishes as lag length increases. For a time series data y_t, the autocovariance between y_t and y_{t-s} is $\mathrm{cov}(y_t, y_{t-s})$ and the variance is $\mathrm{var}(y_t)$. The theoretical autocorrelation is $\rho_s = \frac{\mathrm{cov}(y_t, y_{t-s})}{\mathrm{var}(y_t)}$. However, a nonstationary series: (1) has no long-run mean to which the series returns; (2) has a time dependent variance and goes to infinity as time approaches infinity; and (3) has a theoretical correlation that does not decay or decays very slowly (Enders 1995). The monthly real prices of summer flounder and their autocorrelations are shown in Figures 2.22 and 2.23. In Figure 2.24, the $y-$axis is value of autocorrelation, ρ_s, of summer flounder and the $x-$axis is lag, s. In the two figures, it can be observed that the mean of the monthly real price of summer flounder fluctuates around its average, its variance is stable, and its autocorrelation is cyclical and decays to an insignificant level after about 24 months. These observations from the graphs tend to support stationarity of the real price time series.

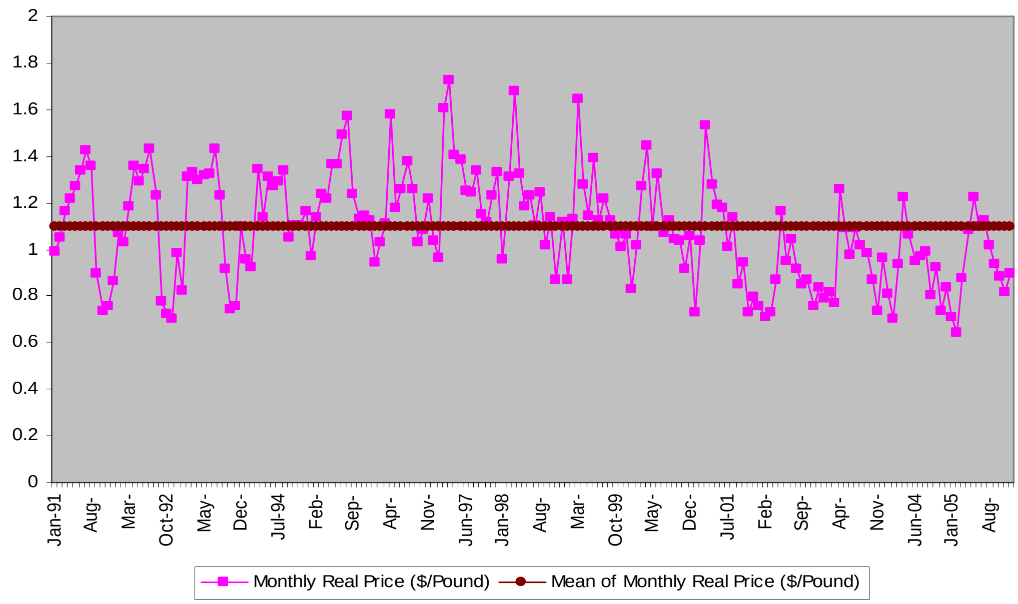

Figure 2.22. Monthly Real Prices of Summer Flounder (Source: Office of Science and Technology, National Marine Fisheries Service)

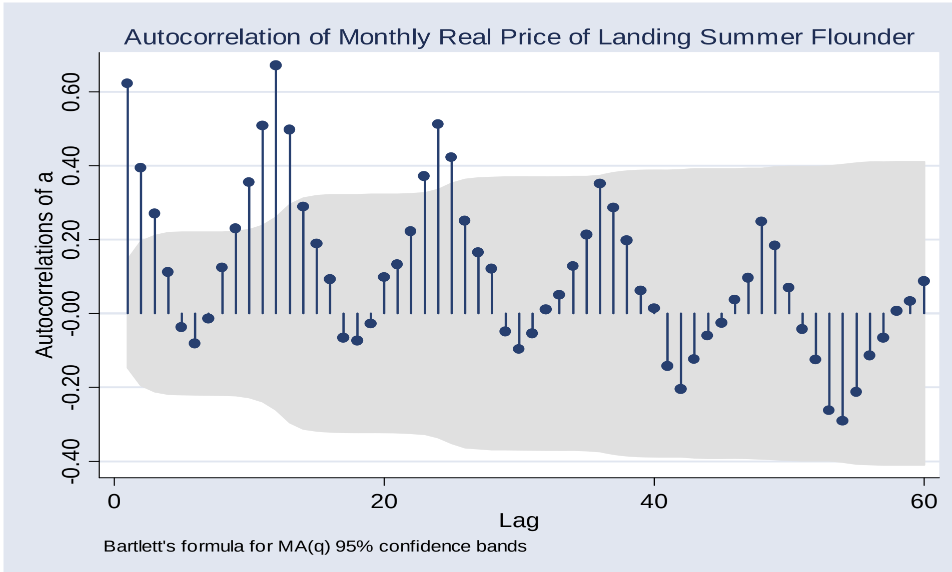

Figure 2.23. Autocorrelation of Monthly Real Prices of Summer Flounder

However, it is not sufficient to judge stationarity or nonstationarity only from graphs and a formal statistical test is required. An augmented Dickey-Fuller (ADF) test (Said and Dickey 1984) is used to test the stationarity of the series. Consider that a variable y_t is generated from a pth -order autoregressive process below:

(2.20) $y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + ... + a_{p-2} y_{t-p+2} + a_{p-1} y_{t-p+1} + a_p y_{t-p} + \varepsilon_t$

where: a_0 is an intercept, $a_1, ..., a_p$ are parameters of lagged values of y_t and ε_t is an i.i.d. error term. Using the methods of the ADF test, the equation is transformed into a new one by adding and subtracting $a_p y_{t-p+1}$. The new equation is

(2.21) $\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{t=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$

where $\gamma = -\left(1 - \sum_{i=1}^{p} a_i\right)$, and $\beta_i = \sum_{j=1}^{p} a_j$. The purpose of the stationarity test is to determine whether or not a unit root exits. In other words, to determine whether or not $\gamma = 0$. If $\gamma = 0$ is accepted, then a unit root exists and y_t is nonstationary. If $\gamma = 0$ is not accepted, then no unit root exists and y_t is stationary. Because whether a constant and/or time trend is included will change the test results, an ADF test including constant and deterministic trend is constructed and the equation is stationary. Because whether or not a constant and/or time trend is included in the model will change the test results (Enders 1995), an ADF test including constant and a time trend is constructed and the equation is:

(2.22) $\Delta y_t = a_0 + \gamma y_{t-1} + a_1 t + \sum_{t=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$

Enders (1995) gives a procedure to test unit roots in this ADF model. In testing a unit root, $t-$tests are inappropriate, and a table specifically designed for unit root test is used. The last problem to consider is that different orders of autoregression and moving averages in error terms ε_t will change the test results. Three different methods, Extended Sample Autocorrelation Function (ESACF, Tsay and Tiao 1984), Minimum Information Criterion (MINIC, Hannan and Tissannen 1982), and Smallest Canonical (SCAN, Tsay and Tiao 1985), are used to identify tentative the orders of ARIMA process. Said and Dickey (1984) have shown that an unknown ARIMA $(p,1,q)$ process can be well approximated by an ARIMA $(n,1,0)$ autoregression of order no more than $T^{1/3}$. In ARIMA $(p,1,q)$, p is the order of autoregression in y_t, 1 represents one unit root in y_t, q is the order of moving averages in error term ε_t. In ARIMA $(n,1,0)$, n is the order of autoregression in y_t. Because the number of observations in this project is 168 and, in approximation, n should not be more than $T^{1/3}$, the tentative order of autoregression is 5.

Table 2.5. Tentative Orders for Estimating ARIMA Models of Summer Flounder Price

	Tentative ARIMA Orders
Original Price	(1,0), (2,1), (4,2), (0,3), (1,3), (1,5)
Log Transformed Price	(1,0), (3,2), (0,3)

The tentative orders of autoregression and moving average, which are identified by these three methods, for the monthly real prices and the corresponding log transformed prices are listed in Table 2.5. In Table 2.5, the first number in parenthesis represents sum of a tentative autoregressive order and a tentative number of unit roots, and the second number represents a tentative order of moving average. For example, in the first original data combination (1,0), the tentative order of autoregression, p, is 1 and the tentative order of moving average, q, is 0; in the second log transformed data (3,2), the tentative order of autoregression, p, is 3 and the tentative order of moving average, q, is 2. After the tentative orders are determined, the next step is to test unit roots. There are six tentative combinations for the original data, and three for the log transformed data. Out of the nine combinations, seven have a moving average in error term ε_t. Based on work of Said and Dickey (1984), models with autoregression of order five are used to approximate those with moving average in unit root tests. The procedure in Enders (1995) is applied to these models. The results indicate the hypothesis of unit root in original or log transformed data is rejected (the procedure of testing unit roots is in Appendix A). Since there is no unit root, $t-$tests are appropriate in statistical inference. ARIMA models for both original and log transformed data are estimated with tentative orders listed in Table 2.5. The forecasted 2005 monthly real prices and their MSE, MAPE, TIC and missing turns are listed in Table 2.6. The forecasted prices are plotted in Figures 2.24, 2.26 and 2.27. Model Three using the original data and Model Two using the log transformed data are the best forecasting models in each category. Both forecasts have the smallest values in all three statistics and less missing turns than other models in their categories. The estimated equations of these two models are in equations (2.23) and (2.24):

$$\text{(2.23)}\quad \underset{}{\Delta fsp_t} = \underset{(0.21325)}{0.57581} - \underset{(0.17203)}{0.46345} \times fsp_{t-1} - \underset{(0.0004006)}{0.0007756} \times t + \underset{(0.04012)}{0.92266} \times \Delta fsp_{t-2} + \varepsilon_t + \underset{(0.023366)}{0.22499} \times \varepsilon_{t-1} - \underset{(0.02352)}{0.97910} \times \varepsilon_{t-2}$$

$$\text{(2.24)}\quad \Delta lfsp = \underset{(0.026205)}{0.07458} - \underset{(0.06250)}{0.34631} \times lfsp_{t-1} - \underset{(0.0002526)}{0.0005734} \times t + \underset{(0.03960)}{0.07559} \times \Delta lfsp_{t-1} - \underset{(0.03801)}{0.92385} \times \Delta lfsp_{t-2} + \varepsilon_t - \underset{(0.02347)}{0.20978} \times \varepsilon_{t-1} + \underset{(0.02377)}{0.97734} \times \varepsilon_{t-2}$$

Table 2.6. Predictions of Real Monthly Price of Summer Flounder in 2005, ARIMA Model Approach

	Original Data Model							Log Transformed Data Model		
Date	**Real Price**	**Model One**	**Model Two**	**Model Three**	**Model Four**	**Model Five**	**Model Six**	**Model One**	**Model Two**	**Model Three**
Jan	0.71	0.89	0.90	0.84	0.98	0.90	0.90	0.88	0.84	0.90
Feb	0.64	0.82	0.82	0.75	0.87	0.82	0.80	0.80	0.73	0.81
Mar	0.87	0.78	0.79	0.82	0.87	0.82	0.76	0.76	0.75	0.78
Apr	1.08	0.91	0.91	0.98	0.98	0.92	0.94	0.90	0.95	0.92
May	1.23	1.02	1.02	1.00	1.11	1.01	1.03	1.02	1.01	1.04
Jun	1.10	1.10	1.10	1.03	1.19	1.08	1.12	1.10	1.05	1.11
Jul	1.12	1.03	1.03	1.04	1.09	1.02	1.04	1.03	1.05	1.01
Aug	1.02	1.05	1.04	1.10	1.10	1.03	1.06	1.04	1.11	1.02
Sep	0.94	0.99	0.99	0.98	1.03	0.98	0.99	0.98	0.98	0.97
Oct	0.88	0.94	0.94	0.89	1.01	0.94	0.94	0.94	0.88	0.94
Nov	0.81	0.91	0.91	0.92	0.97	0.92	0.91	0.90	0.90	0.90
Dec	0.90	0.87	0.87	0.92	0.94	0.89	0.86	0.86	0.89	0.87
MSE		0.0143	0.0145	0.0105	0.0181	0.0144	0.0133	0.0139	0.0108	0.0134
MAPE		0.1129	0.1123	0.0931	0.1335	0.1090	0.1129	0.1100	0.0935	0.1076
TIC		0.0885	0.0889	0.0758	0.0996	0.0887	0.0852	0.0871	0.0769	0.0855
Missing Turns		5	5	3	5	4	4	5	3	6

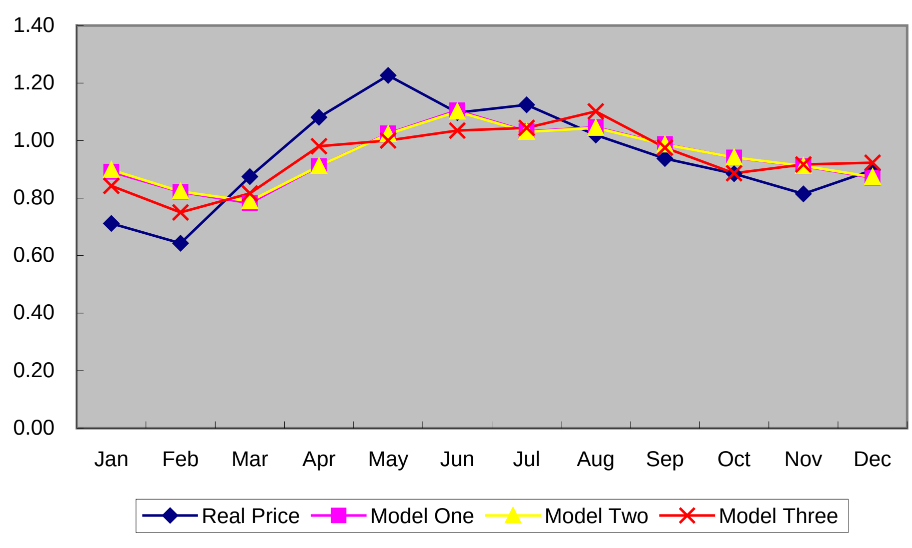

Figure 2.24. Predictions of Real Monthly Price of Summer Flounder in 2005, ARIMA Models One to Three, and the Actual Historical Prices.

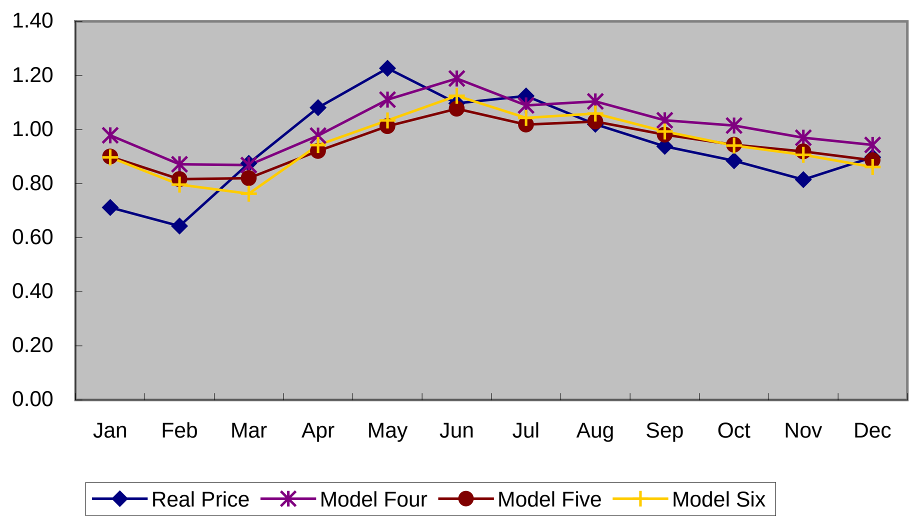

Figure 2.25. Predictions of Real Monthly Price of Summer Flounder in 2005, ARIMA Models Four to Six, and the Actual Historical Prices.

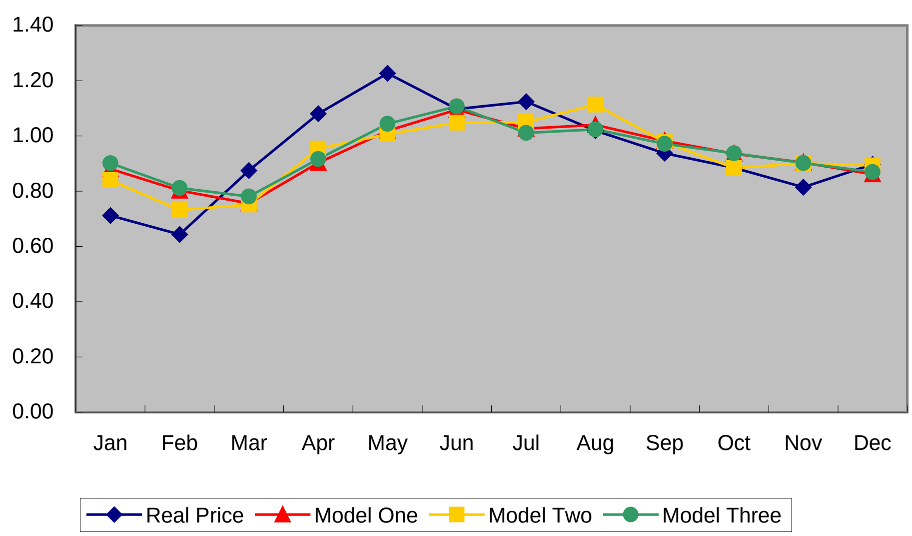

Figure 2.26. Predictions of Real Monthly Price of Summer Flounder in 2005, ARIMA Models One to Three, and the Actual Historical Prices with Log Transformed Data

2.6.2. VAR Model Approach

The second approach used for time series analysis is vector autoregressive (VAR) model. Both the structural model and ARIMA model are single equation models. After estimating these single equation models, it is natural to extend to multiequation models, in which the exogenous variables in the structural model can be considered endogenous. In the model of Group Two of the structural model approach, the log transform of real monthly price of summer flounder is endogenous, but other variables such as the log transform of landings of summer flounder, landings of other types of flounders and imports of frozen flounder are exogenous. Summer flounder prices are expected to affect its future landings and landings and imports of its substitutes. A VAR model is an appropriate framework to include these effects. The VAR model to be estimated includes the variables from the model of Group Two from the structural model approach. The variables are $lfsp$, $lfsq$, $lfaq$, $lfwq$, and $lfoq$. The equation system is:

(2.25) $BX_t = \Gamma_0 + \sum_{l=1}^{p} \Gamma_l X_{t-l} + \varepsilon_t$

, where $X_t = [lfsp_t, lfsq_t, lfaq_t, lfwq_t, lfoq_t]'$, $B = \begin{bmatrix} 1, b_{12}, \ldots\ldots, b_{14} \\ b_{21}, 1, \ldots\ldots, b_{25} \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ b_{51}, b_{52}, \ldots\ldots, 1 \end{bmatrix}$, $\Gamma_0 = [b_{10}, b_{20}, \ldots\ldots, b_{50}]'$,

$\Gamma_l = \begin{bmatrix} \gamma_{11,l}, \gamma_{12,l}, \ldots\ldots, \gamma_{15,l} \\ \gamma_{21,l}, \gamma_{22,l}, \ldots\ldots, \gamma_{25,l} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \gamma_{51,l}, \gamma_{52,l}, \ldots\ldots, \gamma_{55,l} \end{bmatrix}$, and $\varepsilon_t = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \cdots \\ \varepsilon_5 \end{bmatrix}$. Multiplying both sides with B, a standard form is derived:

(2.26) $X_t = A_0 + \sum_{l=1}^{p} A_l X_{t-l} + e_t$

, where $A_0 = B^{-1}\Gamma_0$, $A_l = B^{-1}\Gamma_l$ and $e_t = B^{-1}\varepsilon_t$. This standard form is estimated and used to forecast future prices.

Besides estimating a log transformed data VAR model, an original data VAR model are estimated also, and the original data are fsp, fsq, faq, fwq, and foq, corresponding to the log transformed data in Equation (2.21). Before estimating a VAR model, to tentatively determine autoregression orders, p, is required, just like that in estimating an ARIMA model. Similar to unit roots test for univariate series, other variables must be tested for stationarity or not and if there are several nonstationary series, then the series must be tested to see if there some linear combinations of these nonstationary series exist that will lead to a stationary series. The Enders (1995) procedure for testing unit root indicates that there is no unit root in other variables or their log transforms. So, it is appropriate to test autoregressive (AR) orders directly on the VAR model. Four methods, Partial Autoregressive Matrices (PAM), Partial Correlation Matrices (PCM), Partial Canonical Correlation Matrices (PCCM) and the Minimum Information Criterion (MINIC) method, are applied to tentatively determine the orders. The first three methods suggest an autoregression order of 12 for both original and log transformed data, but the MINIC method suggests AR order of 4 for these two types of data. The VAR models with tentative AR orders of 4 and 12 are estimated for both types of data, original and log transformed data. The monthly real prices in 2005 are forecasted. The forecasting of models with AR of 4 is much poorer and not reported. The forecasting of models with AR 12 are listed in Table 2.7, and plotted in Figure 2.27. The estimated VAR systems are recorded in equations (2.27) and (2.28).

Table 2.7. Predictions of Real Monthly Price of Summer Flounder in 2005, VAR Model Approach

Date	Real Price	Original Data	Log Transformed Data
Jan	0.71	0.92	0.84
Feb	0.64	0.87	0.78
Mar	0.87	0.98	0.92
Apr	1.08	1.26	1.16
May	1.23	1.10	1.09
Jun	1.10	1.08	1.10
Jul	1.12	1.08	1.06
Aug	1.02	1.02	1.01
Sep	0.94	0.95	0.88
Oct	0.88	0.95	0.90
Nov	0.81	0.89	0.80
Dec	0.90	0.93	0.86
RMSE		0.0144	0.006
MAPE		0.1120	0.0699
TIC		0.0886	0.0572
Missing Turns		2	3

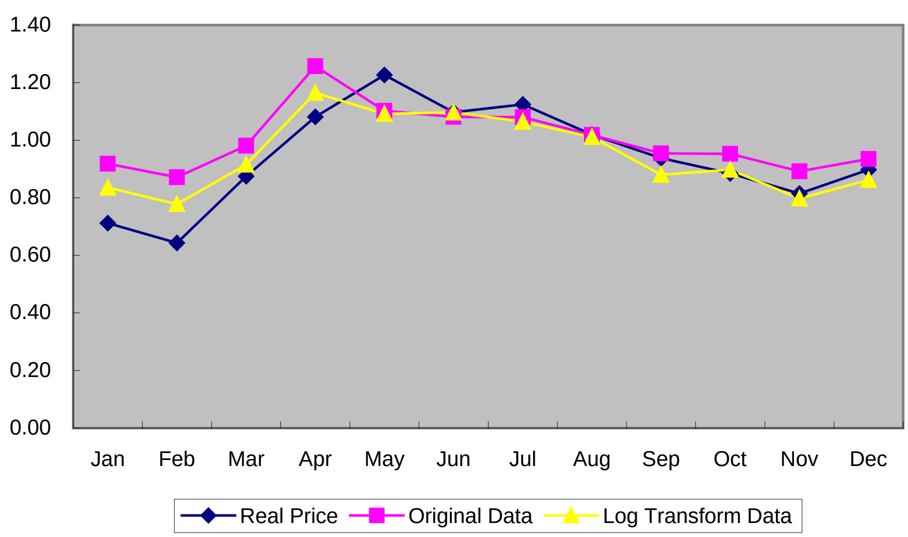

Figure 2.27. Predictions of Real Monthly Price of Summer Flounder in 2005, VAR Model, Original and Log Transformed Data

$$
(2.27)\quad \left\{
\begin{aligned}
fsp_t &= 0.23787\times fsp_{t-1} - 0.06325\times fwq_{t-1} + 0.27244\times fsp_{t-2} + 0.07448\times fsq_{t-2} \\
&\qquad (0.05646) \qquad\qquad (0.02255) \qquad\qquad (0.06260) \qquad\qquad (0.01320) \\
&\quad - 0.07790\times foq_{t-2} - 0.02962\times fsq_{t-3} + 0.04247\times fsq_{t-5} + 0.10143\times fsp_{t-6} \\
&\qquad (0.02563) \qquad\qquad (0.01226) \qquad\qquad (0.01111) \qquad\qquad (0.04353) \\
&\quad + 0.03140\times fsq_{t-7} + 0.05214\times fwq_{t-7} + 0.3940\times fsp_{t-12} \\
&\qquad (0.01259) \qquad\qquad (0.02491) \qquad\qquad (0.05497) \\
fsq_t &= 1.44578 + 0.21862\times foq_{t-2} + 0.27279\times faq_{t-3} - 0.45212\times fsp_{t-4} + 0.56332\times faq_{t-8} \\
&\qquad (0.41862)\ (0.10614) \qquad\qquad (0.11663) \qquad\qquad (0.20560) \qquad\qquad (0.15795) \\
&\quad + 0.10333\times fsq_{t-9} - 0.52928\times faq_{t-9} - 0.47983\times fsp_{t-10} - 0.10466\times fsq_{t-10} \\
&\qquad (0.04850) \qquad\qquad (0.15052) \qquad\qquad (0.24757) \qquad\qquad (0.05913) \\
&\quad + 0.58672\times fsq_{t-12} - 0.33320\times fwq_{t-12} \\
&\qquad (0.05437) \qquad\qquad (0.10615) \\
faq_t &= -0.58634 + 0.22636\times fsp_{t-1} + 0.49389\times faq_{t-1} + 0.21645\times fsp_{t-3} + 0.17443\times fwq_{t-6} \\
&\qquad (0.14538)\ (0.07401) \qquad\qquad (0.05642) \qquad\qquad (0.07865) \qquad\qquad (0.03950) \\
&\quad + 0.05956\times fsq_{t-7} + 0.10490\times foq_{t-8} - 0.07802\times fsq_{t-10} - 0.09151\times fwq_{t-10} \\
&\qquad (0.02086) \qquad\qquad (0.02947) \qquad\qquad (0.01806) \qquad\qquad (0.03769) \\
&\quad - 0.014129\times fsq_{t-12} + 0.31882\times faq_{t-12} \\
&\qquad (0.01852) \qquad\qquad (0.05171) \\
fwq_t &= 0.57444 + 0.13160\times faq_{t-1} + 0.45129\times fwq_{t-1} - 0.09437\times foq_{t-2} - 0.12941\times fwq_{t-3} \\
&\qquad (0.10906)\ (0.06037) \qquad\qquad (0.05549) \qquad\qquad (0.04425) \qquad\qquad (0.04771) \\
&\quad + 0.18776\times faq_{t-5} + 0.12282\times fwq_{t-5} + 0.05854\times fsq_{t-7} - 0.30648\times faq_{t-7} \\
&\qquad (0.06305) \qquad\qquad (0.05054) \qquad\qquad (0.02414) \qquad\qquad (0.05945) \\
&\quad - 0.04611\times fsq_{t-8} - 0.04579\times fsq_{t-9} - 0.10586\times foq_{t-9} - 0.05712\times fsq_{t-10} \\
&\qquad (0.02398) \qquad\qquad (0.02425) \qquad\qquad (0.03780) \qquad\qquad (0.02226) \\
&\quad - 0.07344\times fsq_{t-12} + 0.43144\times fwq_{t-12} \\
&\qquad (0.02572) \qquad\qquad (0.05984) \\
foq_t &= 0.41196\times foq_{t-1} + 0.12394\times fwq_{t-2} - 0.18545\times faq_{t-1} - 0.09508\times fsq_{t-6} \\
&\qquad (0.06517) \qquad\qquad (0.06298) \qquad\qquad (0.08792) \qquad\qquad (0.03543) \\
&\quad + 0.18888\times faq_{t-6} - 0.11086\times foq_{t-8} - 0.38893\times fsp_{t-9} + 0.18771\times fwq_{t-10} \\
&\qquad (0.08730) \qquad\qquad (0.05668) \qquad\qquad (0.15701) \qquad\qquad (0.06685) \\
&\quad + 0.36892\times fsp_{t-11} + 0.15037\times fsq_{t-11} + 0.19024\times faq_{t-11} + 0.27137\times foq_{t-12} \\
&\qquad (0.14752) \qquad\qquad (0.04505) \qquad\qquad (0.08218) \qquad\qquad (0.06029)
\end{aligned}
\right.
$$

$$
(2.28)\quad \begin{cases}
lfsp_t = 0.23680\times lfsp_{t-2} - 0.08209\times lfwq_{t-2} - 011015\times lfoq_{t-2} - 0.03240\times lfsq_{t-3} \\
\qquad (0.05492) \qquad (0.01776) \qquad (0.03047) \qquad (0.01503) \\
\qquad +0.07200\times lfsq_{t-5} + 0.27508\times lfsp_{t-6} + 0.06092\times lfsq_{t-6} - 0.03176\times lfsq_{t-8} \\
\qquad (0.01767) \qquad (0.06676) \qquad (0.01966) \qquad (0.01680) \\
\qquad +0.29683\times lfsp_{t-12} - 0.04308\times lfsq_{t-12} \\
\qquad (0.06952) \qquad (0.02140) \\
lfsq_t = 0.16373\times lfsq_{t-2} + 0.14370\times lfwq_{t-2} + 0.31758\times lfoq_{t-2} - 0.36040\times lfsp_{t-4} \\
\qquad (0.05559) \qquad (0.06377) \qquad (0.10218) \qquad (0.16108) \\
\qquad +0.10452\times lfaq_{t-4} - 0.17005\times lfsq_{t-5} + 0.19332\times lfsq_{t-8} + 0.19444\times lfoq_{t-8} \\
\qquad (0.05996) \qquad (0.06239) \qquad (0.06184) \qquad (0.08413) \\
\qquad +0.10453\times lfsq_{t-9} + 0.45523\times lfsq_{t-12} - 0.27737\times lfwq_{t-12} \\
\qquad (0.05543) \qquad (0.06836) \qquad (0.06624) \\
lfaq_t = -0.11322 + 0.37688\times lfsp_{t-1} + 0.43142\times lfaq_{t-1} + 0.09788\times lfwp_{t-1} + 0.16146\times lfaq_{t-3} \\
\qquad (0.04085) \quad (0.16649) \qquad (0.06224) \qquad (0.04390) \qquad (0.06752) \\
\qquad -0.18595\times lfaq_{t-4} + 0.14239\times lfwq_{t-6} + 0.39486\times lfsp_{t-7} + 0.15249\times lfsq_{t-7} \\
\qquad (0.06716) \qquad (0.03696) \qquad (0.15008) \qquad (0.04292) \\
\qquad +0.18191\times lfaq_{t-9} + 0.18582\times lfoq_{t-9} + 0.36179\times lfaq_{t-12} \\
\qquad (0.05039) \qquad (0.05533) \qquad (0.05922) \\
lfwq_t = 0.49609\times lfwq_{t-1} - 0.21141\times lfsp_{t-2} - 0.23204\times lfwq_{t-3} + 0.15239\times lfwq_{t-4} \\
\qquad (0.05364) \qquad (0.11779) \qquad (0.05224) \qquad (0.05303) \\
\qquad -0.15020\times lfaq_{t-7} - 0.09683\times lfsq_{t-8} - 0.16226\times lfwq_{t-8} + 0.10575\times lfwq_{t-10} \\
\qquad (0.04611) \qquad (0.03761) \qquad (0.04388) \qquad (0.03893) \\
\qquad +0.17576\times lfaq_{t-11} - 0.14498\times lfsq_{t-12} + 0.40883\times lfwq_{t-12} \\
\qquad (0.05158) \qquad (0.03662) \qquad (0.05777) \\
lfoq_t = 0.10199 + 0.46862\times lfoq_{t-1} + 0.09364\times lfwq_{t-6} - 0.32215\times lfsp_{t-9} - 0.17287\times lfoq_{t-10} \\
\qquad (0.03164) \quad (0.06665) \qquad (0.03418) \qquad (0.11236) \qquad (0.07095) \\
\qquad +0.12304\times lfsq_{t-11} + 0.26197\times lfoq_{t-11} - 0.10307\times lfsp_{t-12} \\
\qquad (0.03462) \qquad (0.07373) \qquad (0.03447) \\
\qquad +0.36892\times fsp_{t-11} + 0.15037\times fsq_{t-11} + 0.19024\times faq_{t-11} + 0.27137\times foq_{t-12} \\
\qquad (0.14752) \qquad (0.04505) \qquad (0.08218) \qquad (0.06029)
\end{cases}
$$

2.7. Forecasting Evaluation and Model Selection

Five candidate models are chosen for the further forecasting evaluation. One candidate model is from the structural model approach, and the other four are from time series approach, which has four sub-approaches, original data and log transformed data ARIMA and original data and log transformed data VAR. The statistics and the number of missing turns indicate that the *Group Two* model of structural model approach has the best forecasting performance out of all the five candidate models for real monthly prices of summer flounder in 2005.

After evaluating the accuracy of forecasting, the residuals of Group Two of the structural model approach are evaluated in the optimality test and time improvement test. These test results are contained in Table 2.8. For the forecast bias test, $\alpha = 0$ can't be rejected with a significance level of 5% and the forecast is unbiased. For the delta efficiency test, $\delta = 0$ can't be rejected with a significance level of 5% and the residuals don't contain any price information. So, the forecast is delta efficient. For the gamma efficiency test, $\gamma = 0$ can't be rejected with a significance level of 5% and the residuals are not autocorrelated. The three test results indicate the forecast is gamma efficient. The forecast is unbiased, delta efficient and gamma efficient, so the forecast from Group Two of structural model approach is an optimal forecast. Lastly, in tests of whether model forecasts improve or get worse across time, $\theta_2 = 0$ is not rejected with a significance level of 5%. That is the forecast neither improves or gets worse across time passes. So, the series tests on out-of-sample forecast residuals indicate that Group Two of the structural model is acceptable.

Table 2.8. Optimality Test and Time Improvement Test for Out-of-Sample Residuals for Group Two, Structural Model Approach

	Test for Optimality			
	Forecast Bias Test	Delta Efficiency Test	Gamma Efficiency	Time Improvement or Worsening Test
Estimate	-0.0142	0.0441	0.1017	0.0003
Std Error	0.0201	0.1435	0.3149	0.0038
***p*-value**	0.4944	0.7650	0.7533	0.9480

The goodness-of-fit and diagnostic tests for Group Two of the structural model are listed in Table 2.10. The R^2 and adjusted R^2 of the estimation are 0.8813 and 0.8679 respectively. The diagnostic tests are calculated from estimation residuals. The Durbin-Watson statistic is 1.9901 indicating no autocorrelation in residuals. Both White's test and Breusch-Pagan tests are tests for homoskedasticity. The results in Table 2.10 imply that the residual is homoskedastic and does not vary through time. The Augmented Dickey-Fuller test indicates that residuals are stationary and don't contain a unit root. Lastly, the Shapiro-Wilk test shows that the hypothesis that the residuals are standard normally distributed can't be rejected. So, by the diagnostic test results, the model is very well specified.

2.8. Economic Analysis of the Selected Model

The logarithm of monthly price of landing summer flounder is expressed as a linear function below

$$\begin{aligned}(2.19)\quad lfsp &= 0.141867 + 0.060426M_3 - 0.11625M_{11} - 0.05824M_{12} + 0.085059Y_{94} + 0.159146Y_{95} \\ &+ 0.098475Y_{97} - 0.13164Y_{01} - 0.20382Y_{02} - 0.16895Y_{03} - 0.17652Y_{04} - 0.24208 \times lfsq \\ &- 0.1081 \times \left(lfsq\right)^2 - 0.12919 \times lfsq \times lfaq - 0.28858 \times lfsq \times lfoq + 0.291496 \times lfsq \times QI \\ &- 0.19049 \times lfaq \times lfoq + 0.266235 \times lfaq \times QI\end{aligned}$$

Based on the estimated function, flexibilities of monthly price are calculated. The sample averages of variables are used in calculations. The equation to calculate monthly price flexibilities is:

(2.29) $\frac{\partial fsp}{\partial M_i} = \frac{\partial lfsp}{\partial M_i} \times fsp$

, where fsp is the monthly price of summer flounder and $i \in I = \{3, 11, 12\}$.

$\frac{\partial fsp}{\partial M_3} = 0.1073$, $\frac{\partial fsp}{\partial M_{11}} = -0.2065$, and $\frac{\partial fsp}{\partial M_{12}} = -0.1035$. The estimation indicates that the monthly price of summer flounder increases around 10 cents per pound in March, decreases around 20 cents in November, and decreases around 10 cents in December. So, in these months, there is a seasonal effect in the monthly price of summer flounder. In other months, the monthly effects are not significant. The fluctuations in these months are attributed to monthly fluctuations of summer flounder quantity and its substitutes' quantities. Similarly, the yearly flexibilities of price are calculated by the equation:

(2.30) $\frac{\partial fsp}{\partial Y_i} = \frac{\partial lfsp}{\partial Y_i} \times fsp$

, where $i \in I = \{94, 95, 97, 01, 02, 03, 04\}$. $\frac{\partial fsp}{\partial Y_{94}} = 0.1511$, $\frac{\partial fsp}{\partial Y_{95}} = 0.2827$, $\frac{\partial fsp}{\partial Y_{97}} = 0.1749$,

$\frac{\partial fsp}{\partial Y_{01}} = \text{-}0.2338$, $\frac{\partial fsp}{\partial Y_{02}} = \text{-}0.3621$, $\frac{\partial fsp}{\partial Y_{03}} = \text{-}0.3001$, and $\frac{\partial fsp}{\partial Y_{04}} = \text{-}0.3136$. The annual effects are positive in 1994, 1995 and 1997, but negative in years from 2001 to 2004. The ex-dock landing of summer flounder, Atlantic flounder and winter flounder and imports of frozen flounder supply flexibilities of the monthly price of summer flounder are calculated. The summer flounder landing flexibility of price is calculated by the following equation:

(2.31) $\frac{\partial lfsp}{\partial lfsq} = -0.24208 - 2 \times 0.1081 * lfsq - 0.12919 \times lfaq - 0.28858 \times lfoq + 0.291496 \times QI$

$$+ 0.291496 \times lfsp \times \frac{\partial QI}{\partial lfsq} + 0.266235 \times lfaq \times \frac{\partial QI}{\partial lfsq}$$

where

(2.32) $\frac{\partial QI}{\partial lfsq} = \frac{fsp \times \sum_{i \in I} m_i - fsp^2 \times fsq}{\left(\sum_{i \in I} m_i \right)^2} \times fsq$

fsp is the monthly price of summer flounder, and fsq is the monthly landing of summer flounder, $i \in I = \{fs, fa, fw, fo\}$, and m_i is the monthly ex-dock value and import value in dollars of landed and imported fish. The summer flounder landing flexibility is –0.11. With a 1% increase in the monthly landing of summer flounder, the monthly real price of summer flounder decreases 0.11%. The summer flounder price is relatively inflexible to its landings. Equation (2.33) calculates the cross-flexibility of summer flounder prices to monthly landing quantities of Atlantic flounder.

(2.33) $\frac{\partial lfsp}{\partial lfaq} = -0.12919 \times lfsq + 0.291496 \times lfsq \times \frac{\partial QI}{\partial lfaq} - 0.19049 \times lfoq + 0.266235 \times QI$

$$+ 0.266235 \times lfaq \times \frac{\partial QI}{\partial lfaq}$$

where

(2.34) $\frac{\partial QI}{\partial lfaq} = \frac{fap \times \sum_{i \in I} m_i - fap^2 \times faq}{\left(\sum_{i \in I} m_i \right)^2} \times faq$,

and fap is the monthly price of Atlantic flounder, and faq is the monthly landing of Atlantic flounder. The Atlantic flounder quantity flexibility of monthly price of summer flounder is 0.09. With a 1% increase in the monthly landing of Atlantic flounder, the monthly real price of summer flounder increases 0.09%. This finding is contradicts to the assumption that Atlantic flounder is a substitute for summer flounder and therefore an increase in the supply of Atlantic flounder will decrease the price of summer flounder. However, it should be noted that the estimated equation is not derived from a distance function in consumer theory and the flexibilities calculated are not compensated ones that require constant utility in the analysis and are discussed in Section 2.2.1. The negative sign isn't guaranteed if they are really substitutes. The flexibilities just show how one ex-dock price changes with other prices changing and a constant utility doesn't exist in this analysis. Equation (2.35) calculates the cross-flexibility of summer flounder prices to monthly landing quantities of winter flounder:

$$(2.35)\quad \frac{\partial lfsp}{\partial lfwq} = 0.291496 \times lfsq \times \frac{\partial QI}{\partial lfwq} + 0.266255 \times lfaq \times \frac{\partial QI}{\partial lfwq},$$

where

$$(2.36)\quad \frac{\partial QI}{\partial lfwq} = \frac{fwp \times \sum_{i \in I} m_i - fwp^2 \times fwq}{\left(\sum_{i \in I} m_i\right)^2} \times fwq,$$

and fwp is the monthly price of winter flounder, and fwq is the monthly landing of winter flounder. The winter flounder quantity flexibility of monthly price of summer flounder is –0.01. With a 1% increasing in the monthly landing of winter flounder, the monthly real price of summer flounder decreases 0.01%. The monthly price of summer flounder is not flexible to the landing of winter flounder. Equation (2.33) calculates the cross-flexibility of summer flounder prices to monthly imports of frozen flounder.

$$(2.37)\ \frac{\partial lfsp}{\partial lfoq} = -0.28858 \times lfsq + 0.291496 \times lfsq \times \frac{\partial QI}{\partial lfoq} - 0.19049 \times lfaq + 0.266235 \times lfaq \times \frac{\partial QI}{\partial lfoq}$$

where

$$(2.38)\ \frac{\partial QI}{\partial lfoq} = \frac{fop \times \sum_{i \in I} m_i - fop^2 \times foq}{\left(\sum_{i \in I} m_i\right)^2} \times foq\ .$$

and fop is the monthly price of imported frozen flounder, and foq is the monthly import of frozen flounder. The imported frozen flounder quantity flexibility of monthly price of summer flounder is –0.08. With a 1% increasing in the monthly import of frozen flounder, the monthly price of it decreases 0.08%. The monthly price of summer flounder is not flexible to the import of frozen flounder. The scale flexibility is calculated by equation (2.39):

$$(2.39)\ \frac{\partial lfsp}{\partial QI} = 0.291496 \times lfsq + 0.266235 \times lfaq$$

The scale flexibility is –0.07. Consider that

$$\begin{aligned}(2.40)\ QI &= lfsq \times w_{fs} + lfaq \times w_{fa} + lfwq \times w_{fw} + lfoq \times w_{fo} \\ &= \ln\left(fsq^{w_{fs}} \times faq^{w_{fa}} \times fwq^{w_{fw}} \times foq^{w_{fo}} \right)\end{aligned}$$

and set $wgm = fsq^{w_{fs}} \times faq^{w_{fa}} \times fwq^{w_{fw}} \times foq^{w_{fo}}$, where wgm is the weighted geometric mean of the landing and exported quantities. Thus, $\frac{\partial lfsp}{\partial QI}$ calculates the flexibility of the monthly price of summer flounder to the weighted geometric mean of all the quantities. With 1% increase in the weighted geometric mean of all the quantities of flounder, the monthly price of summer flounder will decrease 0.07%. The results above indicate that the monthly real price of summer flounder isn’t very flexible to either its own supply, or supply of substitutes or their total supply.

2.9. Conclusions

Two methods of estimation are compared in terms of forecasting accuracy and missing turns. The final model with the best forecasting is Group Two, from the structural model approach. A series of regressions on the model residuals are run to evaluate the estimation of Group Two. The results indicate that the forecasting is optimal and efficient. Diagnostic tests show that the model is statistically adequate. The structural model of Group Two is a log transformed data model. The log transformed data model will be applied in the second stage of this project to maximize the revenue from summer flounder. The flexibilities indicate that seasonal effects exist in the monthly price of summer flounder. The own supply flexibility of monthly price is small. When the monthly landing of summer flounder increases 1%, the monthly price decreases 0.11%. The cross supply flexibilities of monthly price of summer flounder are also small relative to the quantities of Atlantic flounder, winter flounder and imported frozen flounder. The scale flexibility of the monthly price to the weighted geometric mean of all the quantities is also very low.

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Chapter Three

A Revenue Maximization Model for Landing Summer Flounder — Stage Two of Managing Flounder Openings for Maximum Revenue

3.1. Introduction

In Chapter Two, a trans-log inverse demand model was estimated to describe the fluctuation of summer flounder monthly prices. In the second stage, the estimated demand model is incorporated into a revenue-maximizing mathematical programming model. The model maximizes revenue by allocating the annual federal landing quota over 12 months. The trans-log model was estimated as

$$(3.1)\quad \begin{aligned} lfsp &= 0.141867 + 0.060426M_3 - 0.11625M_{11} - 0.05824M_{12} + 0.085059Y_{94} + 0.159146Y_{95} \\ &+ 0.098475Y_{97} - 0.13164Y_{01} - 0.20382Y_{02} - 0.16895Y_{03} - 0.17652Y_{04} - 0.24208\times lfsq \\ &- 0.1081\times(lfsq)^2 - 0.12919\times lfsq\times lfaq - 0.28858\times lfsq\times lfoq + 0.291496\times lfsq\times QI \\ &- 0.19049\times lfaq\times lfoq + 0.266235\times lfaq\times QI \end{aligned}$$

where $lfsp$ is the logarithm of monthly real prices of summer flounder, $lfsq$ is the logarithm of monthly landings of summer flounder, $lfaq$ is the logarithm of monthly landings of Atlantic flounder, $lfoq$ is the logarithm of monthly imports of frozen flounder, QI is a quantity index, M_3, M_{11}, and M_{12} are monthly dummy variables for March, November and December, Y_{94} is the a dummy variable for 1994, Y_{95} is the a dummy variable for 1995, Y_{97} is the a dummy variable for 1997, Y_{01} is the a dummy variable for 2001, Y_{02} is the a dummy variable for 2002, Y_{03} is the a dummy variable for 2003, and Y_{04} is the a dummy variable for 2004. The quantity index is computed by the following equation

$$(3.2)\quad QI = lfsq\times w_{fs} + lfaq\times w_{fa} + lfwq\times w_{fw} + lfoq\times w_{fo}$$

where $w_i = \frac{m_i}{\sum_{i \in I} m_i}$, $i \in I = \{fs, fa, fw, fo\}$, $lfwq$ is the logarithm of monthly landings of winter flounder, fs represents summer flounder, fa represents Atlantic flounder, fw represents winter flounder, fo represents imported frozen flounder and m_i is the monthly ex-dock value or import value in dollars.

Using the monthly demand estimates, the industry annual revenue from summer flounder landing will be maximized by optimally allocating the quota amongst the months. A mathematical programming model will be used to do this. Each year the National Marine Fisheries Service (NMFS) sets the total allowable catch for summer flounder and other species after measuring the stock level and making a judgment about what catch can be allowed if the fishery is to be in compliance with *Magnuson-Stevens Fishery Conservation and Management Act*. Then given the total allocation from NMFS, each of the states, that traditionally landed summer flounder, gets a percentage of the total allowable landing (TAL). The percentage of the TAL was based on historical landing records of each of the states. That percentage has stayed the same across time. Table 3.1 shows that there are eight states sharing the annual federal landing quota, among which the quotas of North Carolina and Virginia are greater than two million pounds, the quotas of New Jersey and Rhode Island are greater than one million pounds, the quotas of New York and Massachusetts are greater than five hundred thousand pounds, and the quotas of Connecticut and Maryland are less than five hundred thousand pounds. A *One Area and One Constraint* model is constructed and solved. For the *One Area and One Constraint* model, there is a constraint representing the total annual quota, but there is no constraint representing each state's quota indicated in Table 3.1.

There are two reasons to set up this *One Area and One Constraint* model. First, for each state, the quota is almost endowment and rarely does a state government transfer any part of its quota to other states. It is common for a fisherman, who catches summer flounder off the coast of one state, New Jersey for example, to land the catch at the port of another, like Virginia. Obviously a fisherman will tend to fish where the concentration of fish is the greatest and then land the fish where is legally can. Secondly, the *One Area and One Constraint* model is a simple model and it can be used as a starting point for examining more complicated models with multi-constraints on monthly landings. The term *One Area and One Constraint* is shortened to *One Constraint* in the following text, tables and figures.

This chapter is organized into seven sections. A brief description of scenario analyses is discussed in Section 3.2. In section 3.3, a *One Constraint* scenario is constructed and solved as a benchmark for other scenarios. Section 3.4 optimizes monthly catch in the Atlantics but constrains it by using experienced fishermen's estimates of how much of the total quota could be caught in any one month. Section 3.5 discusses the patterns of monthly landings and real prices of summer flounder suggested by the optimization models in the previous two sections. Section 3.6 compares the annual total revenues derived from the optimization models and those implied by the historical data from 1991 to 2005. A conclusion section is at the end of this chapter.

Table 3.1. Summer Flounder Quota Allocation in Mid-Atlantic States

	CN	MD	MA	NJ	NY	NC	RI	VA	
Jan			15%,		20%,				
Feb			105,039	469,869	157,025			64.3%,	
Mar			(to Apr.		16%,	80%,	54%,	1,375,260	
Apr			22)	184,591	125,620	2,254,313	869,491		
May								6.4%,	
Jun			70%,	176,201	27%,			136,884	
Jul			490,184		211,983		35%,		
Aug			(from	176,201			563,559		
Sep			Apr.		27%,			0%	
Oct			23)	486,650	211,983	0%			
Nov	2.3%,	2.0%,	15%,		10%,	20%,	11%,	29.3%,	
Dec	231,737	209,356	105,039	184,591	78,512	563,578	177,118	626,674	
Total (lbs)	231,737	209,356	700,262	1,678,103	785,123	2,817,891	1,610,168	2,138,818	10,171,458

Source: Electronic Code for Federal Regulations

3.2. Scenario Analyses

In constructing and solving the revenue maximization model, various scenarios are evaluated. The first scenario is a *One Constraint* model and is discussed in section three. In this scenario, the twelve decision making variables are monthly landings of summer flounder in 2007 and the one constraint is that the total annual landing is less than or equal the federal quota. This scenario doesn't consider upper bounds of monthly landings in different months, but it can be used as a benchmark to evaluate effects imposed by other constraints in different scenarios.

However, experienced fishermen feel that, if permitted, the federal quota could be filled in a few months. Regulators don't ever allocate the quota to just several months lest the price of summer flounder collapse. The various scenarios in section four add constraints based on fishermen's estimates, obtained from three experienced fishermen, of the maximum percentage of the total quota that could be landed in a given month. The first two scenarios are based on the maximum monthly catch percentages obtained from two experienced fishermen respectively. The optimization models using these two estimates are called *Fisherman A* and *Fisherman B* scenario. In the third scenario, an average estimate of the percentage obtained from three fishermen is used and the model is called *Average* scenario. Since fisherman B estimated no landing in May and August, a *Not Extreme* scenario is evaluated allowing landings in May and August. The scenarios reflect fishermen's estimates of landing quantity based on their experience. So, these scenarios with monthly constraints in section four are more practical than the *One Constraint* scenario in section three. For the models with monthly constraints in all scenarios, their maximum revenues should be less than without monthly constraint.

3.3. One Constraint Scenario

3.3.1. The Optimization Model

The revenue maximization problem for the *One Constraint* scenario is

(3.3) $$\max_{fsq_i} \; r = \sum_{i=1}^{12} fsp_i \times fsq_i$$

subject to

(3.4) $$\sum_{i=1}^{12} fsq_i \leq Quota \,,$$

(3.5) $$fsq_i \geq 0 \,,$$

where: fsp_i is the monthly real price of summer flounder in 2007 predicted by the inverse demand function, and fsq_i is the monthly landing of summer flounder in 2007 as selected by the model. Kuhn-Tucker conditions for this problem are:

$$(3.6)\ L = \sum_{i=1}^{12} fsp_i \times fsq_i - \lambda\left(\sum_{i=1}^{12} fsp_i - Quota\right)$$

Then the First Order Condition (FOC.) satisfy that

$$(3.7)\ \frac{\partial L}{\partial fsq_i} \le 0, \quad fsq_i \times \frac{\partial L}{\partial fsq_i} = 0, \quad \frac{\partial L}{\partial \lambda} \ge 0, \ \ \lambda \frac{\partial L}{\partial \lambda} = 0$$

and Second Order Condition (SOC) satisfy that the augmented Hessian matrix is negative semi definite (Necessary Condition)

Since the logarithm of monthly real price is estimated in the first stage of this project, the objective function is changed to an exponential function of a sum of two log values (log prices and log quantities). The new optimization problem is set up as

The new optimization problem is then set up as:

$$(3.8)\ \max_{lfsq_i}\ R = \sum_{i=1}^{12} \exp\left(lfsp_i + lfsq_i\right)$$

subject to:

$$(3.9)\ \sum_{i=1}^{12} \exp\left(lfsq_i\right) \le Quota$$

where *lfsp* is determined by the inverse demand function.

Then the Lagrangian problem is:

$$(3.9)\ L = \sum_{i=1}^{12} \exp\left(lfsp_i + lfsq_i\right) - \lambda\left(\sum_{i=1}^{12} \exp\left(lfsq_i\right) - Quota\right)$$

The FOC is:

$$(3.10)\quad \frac{\partial L}{\partial lfsq_i} = 0, \quad \frac{\partial L}{\partial \lambda} = 0.$$

The SOC requires that the augmented Hessian matrix is negative semidefinite. The solution of the problem is as follows, starting with the first order conditions:

$$(3.11)\quad \frac{\partial L}{\partial lfsq_i} = r_i g_i - \lambda \exp\left(lfsq_i\right) = r_i g_i - \lambda h_i = 0$$

$$(3.12)\quad \frac{\partial L}{\partial \lambda} = \sum_{i=1}^{12} \exp\left(lfsq_i\right) - Quota = 0$$

where:

$$\begin{aligned}(3.13)\quad g_i &= \frac{\partial\left(lfsp_i + lfsq_i\right)}{\partial lfsq_i} \\ &= -0.2421 - 0.2162 \times lfsq_i - 0.1292 \times lfaq_i - 0.2886 \times lfoq_i + 0.2915 \times QI_i \\ &\quad + 0.2915 \times lfsq_i \times w_{fs,i} + 0.2662 \times lfaq_i \times w_{fs,i} + 1 \\ &= 0.7579 - 0.2162 \times lfsq_i - 0.1292 \times lfaq_i - 0.2886 \times lfoq_i \\ &\quad + \left(0.2915 \times lfsq_i + 0.2662 \times lfaq_i\right) w_{fs,i} + 0.2915 \times QI_i\end{aligned}$$

where

$$(3.14)\quad r_i = \exp\left(lfsp_i + lfsq_i\right) = fsp_i \times fsq_i$$

and

$$(3.15)\quad h_i = \exp\left(lfsq_i\right) = fsq_i\,.$$

Since the Hessian matrix is diagonal, only the signs of the diagonal elements need to be checked for the second order conditions as follows:

$$\begin{aligned}(3.16)\quad \frac{\partial^2 L}{\partial lfsq_i^{\,2}} &= r_i^2 g_i^2 + r_i(-0.2162 + 0.2915 \times w_{fs,i} + 0.2915 \times w_{fs,i}) - \lambda h_i \\ &= r_i^2 g_i^2 + r_i(-0.2162 + 0.5830 \times w_{fs,i}) - \lambda h_i \le 0\end{aligned}$$

Failure to satisfy Equation (3.16) is illustrated below in Appendix B when annual rather than average market shares are used to calculate the quantity index and no feasible solutions are found in some years.

3.3.2. The Optimization Revenue

Mathematical programming software, CONPOT Solver of GAMS 21.5 (Brook 1998), is used to solve the revenue maximization problem. Anderson et. al (2003), Lee et. al (2000) and Lee and Gates (2007) apply GAMS in fishery resource management. The unique constraint is the federal quota on landing summer flounder, which is 10,171,458 pounds in 2007. The decision-making variables are monthly landings of summer flounder. It is necessary to specify starting values for the decision-making variables to solve this nonlinear problem and avoid infeasibility and non-optimality. To solve this problem, the initial landing pounds of all months are set at 840,000 pounds, which is less than one twelfth of the total landing quota, which is 847,621.5 pounds.

The monthly landings of the three substitutes, Atlantic, winter, and imported frozen flounder, are put into the model as exogenous variables. However, the most recent data available for these substitutes is 2005. So, the 2005 data of the three substitutes is used together with the 2007 quota to maximize the revenue in 2007. As to the market shares used to calculate the quantity index, there are fifteen years of market shares, from 1991 to 2005, in the data set. CONOPT in GAMS is able to solve the models except for market shares from three years, 1999, 2004, and 2005, which have no optimal solution. The analysis in section 3.1 indicates that this non-optimality may be because in those years the summer flounder market share, $w_{fs,i}$, is greater than the upper bound K_i. Table 3.2 contains the optimization results from models using sixteen sets (1991 to 2005 and their average) of market shares, with 2005 substitute quantities. The upper part of the table contains landing quantities in million pounds, and the lower part of the table contains monthly real prices of the fish in dollars per pound. The highest optimized revenue is $12.87 million in 1997, and the lowest is $11.87 million in 1991. The average of these optimized revenues is $12.48 million with a standard deviation of $0.31 million. Lastly, a model with average market shares from 1991 to 2005 is solved and its revenue is $12.35 million. Based on the revenues and their standard deviation, it can be seen that the optimization model is not very sensitive to the market shares from different years.

3.3.3. Sensitivity Analyses on Substitute Quantities

In the model, there are three substitutes, Atlantic, winter, and imported frozen flounder. It is interesting to see how each substitute in the market affects the maximized revenues. The average market shares from 1991 to 2005 are used for the following models.

First, the optimization model is solved with all the three-substitute quantities changed from 1991 to 2005. The maximized revenue, optimized monthly landings, and real prices of summer flounder are contained in Table 3.3. The highest revenue is $12.35 million using substitute quantities in 2005, and the lowest is $10.42 million using substitute quantities in 1997. The average level is $10.75 million, and its standard deviation is $0.49 million.

Then, one substitute landing or import quantity was allowed to change from 1991 to 2005 while the other quantities were held constant at the 2005 levels. First, Atlantic flounder monthly landing quantities were allowed to change from 1991 to 2005, and the winter and imported frozen flounder quantities were held constant at their 2005 level. The results are contained in Table 3.4. The highest maximum revenue is $12.35 million when monthly Atlantic flounder landing quantities in 2005 are used and the lowest is $10.56 million when monthly Atlantic flounder landing quantities in 1993 are used. The average is $11.05 million and its standard deviation is $0.52 million. Table 3.5 contains the results of sensitivity analysis of revenue to winter flounder landings. The highest maximum revenue is $12.35 million when the monthly winter flounder landings in 2005 are put in the model and the lowest is $11.55 million when those in 1991 are put in the model. The average is $11.87 million and its standard deviation is $0.21 million. The results of changing imported frozen flounder quantities are recorded in Table 3.6. The highest revenue is $12.64 million when the monthly imports in 1991 are used to solve the model and the lowest is $11.36 million when those in 1997 are used to solve the model. The average is $11.90 million with a standard deviation of $0.35 million. A summary of the sensitivity analysis of the revenue to the substitute monthly quantities in the *One Constraint* scenario is contained in Table 3.7. The average optimized revenues for winter and imported frozen flounder are very close at $11.87 million and $11.90 million respectively. The standard deviation indicates that the maximized revenue is the most sensitive to the landings of Atlantic flounder, whose standard deviation is $0.52 million; and is the least sensitive to the winter flounder landings, whose standard deviation is $0.21 million.

Table 3.2. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities in 2005 of All Substitutes, and the Market Shares from 1991 to 2005, One Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pounds)									
	2005	2004	2003	2002	2001	2000	1999	1998	1997
Jan	.	.	0.578	0.518	0.451	0.442	.	0.251	0.191
Feb	.	.	0.407	0.699	0.811	0.562	.	0.783	0.959
Mar	.	.	0.791	1.114	1.254	1.227	.	1.285	1.12
Apr	.	.	1.441	1.215	1.338	1.353	.	1.314	1.221
May	.	.	0.996	1.073	1.019	1.035	.	1.018	0.989
Jun	.	.	0.798	0.757	0.804	0.762	.	0.826	0.716
Jul	.	.	0.954	0.935	0.906	0.825	.	0.985	0.905
Aug	.	.	0.868	0.804	0.813	0.855	.	0.924	0.874
Sep	.	.	0.982	0.813	0.699	0.816	.	0.833	0.791
Oct	.	.	1.064	0.941	0.808	0.953	.	0.856	0.727
Nov	.	.	0.581	0.513	0.549	0.592	.	0.482	0.675
Dec	.	.	0.712	0.789	0.719	0.750	.	0.615	1.005
Monthly Prices of Summer Flounder ($/Pound)									
	2005	2004	2003	2002	2001	2000	1999	1998	1997
Jan	.	.	1.455	1.607	1.587	1.613	.	2.399	3.112
Feb	.	.	1.687	1.386	1.248	1.312	.	1.206	1.231
Mar	.	.	1.461	1.239	1.290	1.203	.	1.248	1.370
Apr	.	.	1.144	1.256	1.187	1.138	.	1.226	1.304
May	.	.	1.172	1.180	1.176	1.147	.	1.276	1.401
Jun	.	.	1.099	1.126	1.063	1.138	.	1.076	1.194
Jul	.	.	1.046	1.097	1.122	1.213	.	1.053	1.110
Aug	.	.	1.173	1.197	1.212	1.225	.	1.124	1.170
Sep	.	.	1.050	1.148	1.200	1.126	.	1.111	1.154
Oct	.	.	1.097	1.159	1.214	1.149	.	1.193	1.287
Nov	.	.	1.119	1.198	1.150	1.106	.	1.221	1.088
Dec	.	.	1.292	1.218	1.287	1.284	.	1.503	1.117
Revenue (One Million Dollars)	.	.	**12.16**	**12.41**	**12.37**	**12.20**	.	**12.48**	**12.87**

Table 3.2. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities in 2005 of All Substitutes, and the Market Shares from 1991 to 2005, One Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pounds)

	1996	1995	1994	1993	1992	1991	Average 91 to 05
Jan	0.383	0.359	0.597	0.565	0.571	0.520	0.443
Feb	0.294	0.744	0.566	0.737	0.712	0.588	0.641
Mar	1.327	1.025	0.996	0.869	0.960	1.045	1.069
Apr	1.448	1.327	1.300	1.327	1.123	1.258	1.285
May	1.011	1.049	1.022	0.963	0.999	1.064	1.026
Jun	0.774	0.834	0.823	0.797	0.839	0.799	0.803
Jul	1.012	1.063	1.093	1.032	1.078	1.016	0.981
Aug	0.785	0.844	0.888	0.893	0.926	0.893	0.875
Sep	0.580	0.831	0.748	0.835	0.882	0.898	0.832
Oct	0.734	0.761	0.66	0.715	0.737	0.819	0.843
Nov	0.778	0.596	0.624	0.613	0.628	0.586	0.597
Dec	1.045	0.739	0.854	0.826	0.717	0.684	0.777

Monthly Prices of Summer Flounder ($/Pound)

	1996	1995	1994	1993	1992	1991	Average 91 to 05
Jan	1.750	1.879	1.445	1.480	1.499	1.492	1.669
Feb	1.981	1.184	1.417	1.339	1.329	1.407	1.336
Mar	1.230	1.272	1.285	1.571	1.486	1.336	1.309
Apr	1.237	1.118	1.234	1.304	1.414	1.193	1.204
May	1.293	1.311	1.439	1.448	1.472	1.085	1.247
Jun	1.154	1.145	1.156	1.086	1.053	1.035	1.102
Jul	1.092	1.087	1.090	1.037	1.019	1.003	1.071
Aug	1.278	1.229	1.179	1.078	1.097	1.063	1.154
Sep	1.391	1.143	1.190	1.077	1.081	1.032	1.119
Oct	1.342	1.337	1.443	1.281	1.259	1.192	1.211
Nov	1.062	1.136	1.151	1.108	1.093	1.109	1.124
Dec	1.178	1.199	1.199	1.228	1.236	1.275	1.237
Revenue (One Million Dollars)	**12.83**	**12.40**	**12.79**	**12.72**	**12.74**	**11.87**	**12.35**

Table 3.3. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities from 1991 to 2005 for All Substitutes, and the *Average Market Shares* from 1991 to 2005, *One Constraint Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.443	0.499	0.513	0.562	0.562	0.566	0.688	0.693
Feb	0.641	0.678	0.799	0.81	0.755	0.544	0.685	0.79
Mar	1.069	1.184	1.033	0.831	0.904	0.746	0.893	0.961
Apr	1.285	1.038	0.925	0.912	0.800	0.785	0.911	0.873
May	1.026	1.311	1.165	0.957	0.882	0.765	0.981	0.993
Jun	0.803	0.809	0.938	1.141	0.766	1.144	0.862	0.839
Jul	0.981	0.827	0.946	0.979	1.129	1.626	1.441	1.007
Aug	0.875	0.834	1.046	0.886	1.202	1.582	0.950	0.904
Sep	0.832	0.768	0.709	1.022	1.011	0.778	0.894	0.757
Oct	0.843	0.943	0.737	0.797	0.842	0.491	0.692	0.837
Nov	0.597	0.546	0.552	0.569	0.598	0.454	0.508	0.65
Dec	0.777	0.735	0.807	0.705	0.719	0.691	0.667	0.869
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.669	1.466	1.318	1.19	1.220	1.231	1.096	1.236
Feb	1.336	1.198	1.11	1.044	1.140	1.325	1.155	1.143
Mar	1.309	1.074	1.072	1.147	1.116	1.210	1.125	1.106
Apr	1.204	1.138	1.137	0.997	1.060	1.069	1.011	1.008
May	1.247	1.140	0.983	1.01	1.010	1.049	0.974	0.984
Jun	1.102	1.067	0.983	0.942	1.059	0.967	1.008	1.021
Jul	1.071	1.070	0.987	0.978	0.953	0.930	0.915	0.972
Aug	1.154	1.043	0.963	1.018	0.932	0.917	0.987	1.001
Sep	1.119	1.049	1.122	0.966	0.971	1.034	1.005	1.067
Oct	1.211	1.023	1.114	1.06	1.031	1.293	1.199	1.042
Nov	1.124	1.047	1.042	1.049	1.006	1.087	1.062	0.984
Dec	1.237	1.087	1.036	1.061	1.025	1.004	1.047	0.965
Revenue (One Million Dollars)	**12.35**	**11.25**	**10.76**	**10.45**	**10.49**	**10.66**	**10.52**	**10.58**

Table 3.3. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities from 1991 to 2005 for All Substitutes, and the Average Market Shares from 1991 to 2005, One Quota Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.543	0.475	0.603	0.586	0.712	0.612	0.886
Feb	0.646	0.690	0.711	0.805	0.847	0.771	1.070
Mar	1.051	0.933	0.970	1.081	1.508	1.302	1.495
Apr	0.961	0.840	0.721	1.078	0.927	1.361	1.111
May	1.246	0.838	0.919	1.272	1.611	2.094	0.773
Jun	0.995	0.889	0.943	0.922	0.758	0.672	0.748
Jul	1.061	0.818	1.029	0.675	0.633	0.514	0.615
Aug	0.952	1.423	0.905	0.730	0.560	0.572	0.683
Sep	0.739	1.200	0.861	0.777	0.604	0.508	0.572
Oct	0.776	0.885	1.231	1.013	0.775	0.655	0.711
Nov	0.523	0.491	0.560	0.579	0.554	0.477	0.714
Dec	0.678	0.687	0.721	0.655	0.682	0.634	0.795
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.244	1.449	1.257	1.187	1.101	1.171	1.074
Feb	1.133	1.152	1.222	1.068	1.050	1.059	1.048
Mar	1.056	1.138	1.104	1.096	0.945	0.976	1.021
Apr	0.980	1.026	1.096	0.958	0.995	0.93	0.963
May	0.945	1.026	1.003	0.955	0.934	0.937	1.057
Jun	0.985	1.007	0.997	0.998	1.060	1.113	1.068
Jul	0.956	1.025	0.971	1.084	1.135	1.231	1.166
Aug	0.979	0.926	0.998	1.061	1.212	1.169	1.121
Sep	1.049	0.941	1.015	1.049	1.192	1.246	1.234
Oct	1.031	0.997	0.932	0.970	1.056	1.113	1.098
Nov	1.020	1.078	1.050	0.987	1.056	1.092	0.958
Dec	1.097	1.046	1.111	1.077	1.074	1.101	1.011
Revenue (One Million Dollars)	**10.42**	**10.58**	**10.66**	**10.49**	**10.58**	**10.66**	**10.74**

Table 3.4. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of Atlantic Flounder from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the Average Market Shares from 1991 to 2005, One Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.443	0.501	0.513	0.519	0.555	0.662	0.605	0.700
Feb	0.641	0.707	0.845	0.840	0.944	0.919	0.865	0.943
Mar	1.069	0.963	0.911	0.927	0.978	0.986	0.955	0.978
Apr	1.285	1.195	1.125	0.856	0.920	0.992	0.948	0.811
May	1.026	1.342	1.017	0.898	0.774	0.793	0.745	0.679
Jun	0.803	0.814	0.82	0.938	0.889	0.882	0.848	0.879
Jul	0.981	0.904	0.969	1.015	1.003	0.984	0.987	1.016
Aug	0.875	0.776	0.811	0.876	0.874	0.825	0.889	0.847
Sep	0.832	0.758	0.876	0.947	0.973	0.966	0.983	0.928
Oct	0.843	0.86	0.818	0.871	0.866	0.796	0.959	0.881
Nov	0.597	0.61	0.669	0.733	0.708	0.674	0.699	0.767
Dec	0.777	0.741	0.798	0.752	0.688	0.693	0.688	0.742
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.669	1.597	1.447	1.320	1.285	1.325	1.376	1.362
Feb	1.336	1.284	1.186	1.098	1.075	1.085	1.125	1.113
Mar	1.309	1.266	1.191	1.132	1.113	1.121	1.150	1.138
Apr	1.204	1.167	1.105	1.044	1.032	1.041	1.061	1.045
May	1.247	1.241	1.157	1.105	1.084	1.089	1.108	1.101
Jun	1.102	1.080	1.042	1.008	1.011	1.011	1.024	1.014
Jul	1.071	1.047	1.006	0.976	0.971	0.977	0.984	0.977
Aug	1.154	1.128	1.082	1.046	1.034	1.041	1.055	1.049
Sep	1.119	1.096	1.044	1.004	0.99	0.995	1.012	1.007
Oct	1.211	1.179	1.119	1.070	1.053	1.061	1.081	1.073
Nov	1.124	1.096	1.043	1.001	0.988	0.995	1.013	1.002
Dec	1.237	1.209	1.157	1.118	1.106	1.111	1.131	1.120
Revenue (One Million Dollars)	**12.35**	**12.10**	**11.41**	**10.85**	**10.72**	**10.83**	**11.03**	**10.96**

Table 3.4. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of Atlantic Flounder from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the Average Market Shares from 1991 to 2005, One Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.639	0.642	0.645	0.596	0.605	0.664	0.652
Feb	0.875	0.942	0.985	0.952	0.944	0.956	1.031
Mar	1.018	1.071	1.022	1.152	0.964	0.960	1.293
Apr	0.836	0.915	0.880	0.875	0.892	0.857	0.948
May	0.723	0.693	0.686	0.696	0.704	0.708	0.695
Jun	0.869	0.877	0.875	0.892	0.920	0.928	0.850
Jul	1.023	0.984	0.987	0.999	1.040	1.043	0.942
Aug	0.823	0.816	0.809	0.805	0.823	0.801	0.778
Sep	0.904	0.935	0.948	0.970	0.992	0.955	0.869
Oct	0.867	0.818	0.808	0.809	0.844	0.842	0.738
Nov	0.762	0.714	0.713	0.703	0.720	0.703	0.689
Dec	0.833	0.764	0.815	0.721	0.722	0.754	0.685
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.339	1.326	1.324	1.293	1.254	1.261	1.366
Feb	1.094	1.090	1.091	1.073	1.041	1.037	1.122
Mar	1.131	1.127	1.123	1.118	1.091	1.087	1.152
Apr	1.040	1.039	1.036	1.028	1.015	1.012	1.055
May	1.094	1.092	1.092	1.085	1.076	1.074	1.103
Jun	1.016	1.013	1.017	1.009	1.002	1.008	1.023
Jul	0.973	0.977	0.976	0.974	0.962	0.969	0.989
Aug	1.046	1.043	1.043	1.039	1.028	1.031	1.056
Sep	1.005	0.998	0.996	0.989	0.977	0.979	1.015
Oct	1.066	1.062	1.061	1.053	1.036	1.034	1.080
Nov	0.996	0.994	0.993	0.987	0.974	0.973	1.008
Dec	1.113	1.109	1.107	1.103	1.091	1.087	1.125
Revenue (One Million Dollars)	**10.88**	**10.85**	**10.85**	**10.74**	**10.56**	**10.58**	**11.07**

Table 3.5. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of Winter Flounder from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the Average Market Shares from 1991 to 2005, One Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.443	0.444	0.448	0.449	0.449	0.446	0.445	0.443
Feb	0.641	0.639	0.639	0.633	0.639	0.643	0.643	0.641
Mar	1.069	1.080	1.084	1.086	1.089	1.086	1.085	1.082
Apr	1.285	1.296	1.298	1.297	1.298	1.302	1.302	1.299
May	1.026	1.030	1.030	1.032	1.033	1.034	1.033	1.031
Jun	0.803	0.794	0.804	0.803	0.805	0.796	0.786	0.788
Jul	0.981	0.981	0.986	0.982	0.986	0.981	0.979	0.983
Aug	0.875	0.882	0.882	0.877	0.891	0.892	0.886	0.887
Sep	0.832	0.834	0.834	0.837	0.838	0.839	0.838	0.836
Oct	0.843	0.839	0.835	0.835	0.824	0.830	0.840	0.832
Nov	0.597	0.583	0.562	0.573	0.554	0.553	0.563	0.578
Dec	0.777	0.769	0.77	0.767	0.766	0.771	0.773	0.772
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.669	1.662	1.613	1.605	1.611	1.659	1.678	1.685
Feb	1.336	1.305	1.298	1.252	1.280	1.300	1.310	1.313
Mar	1.309	1.246	1.223	1.222	1.206	1.239	1.242	1.246
Apr	1.204	1.084	1.098	1.058	1.049	1.074	1.074	1.087
May	1.247	1.169	1.142	1.159	1.156	1.166	1.192	1.194
Jun	1.102	1.126	1.102	1.108	1.104	1.127	1.155	1.145
Jul	1.071	1.075	1.042	1.082	1.069	1.099	1.107	1.075
Aug	1.154	1.124	1.129	1.155	1.091	1.088	1.121	1.105
Sep	1.119	1.095	1.116	1.091	1.084	1.082	1.102	1.098
Oct	1.211	1.177	1.154	1.150	1.112	1.124	1.161	1.140
Nov	1.124	1.092	1.056	1.070	1.042	1.039	1.052	1.079
Dec	1.237	1.156	1.157	1.135	1.123	1.144	1.159	1.162
Revenue (One Million Dollars)	**12.35**	**11.89**	**11.77**	**11.73**	**11.59**	**11.77**	**11.94**	**11.91**

Table 3.5. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of Winter Flounder from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the Average Market Shares from 1991 to 2005, One Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.446	0.445	0.445	0.45	0.45	0.451	0.452
Feb	0.640	0.643	0.641	0.644	0.639	0.636	0.635
Mar	1.083	1.078	1.083	1.085	1.087	1.088	1.091
Apr	1.299	1.300	1.298	1.305	1.301	1.299	1.298
May	1.032	1.032	1.030	1.033	1.033	1.032	1.033
Jun	0.789	0.788	0.777	0.776	0.792	0.799	0.796
Jul	0.982	0.983	0.978	0.967	0.982	0.983	0.984
Aug	0.890	0.885	0.883	0.875	0.882	0.886	0.892
Sep	0.836	0.834	0.834	0.837	0.836	0.836	0.839
Oct	0.827	0.836	0.837	0.84	0.836	0.838	0.83
Nov	0.577	0.578	0.589	0.583	0.561	0.552	0.552
Dec	0.771	0.77	0.775	0.777	0.774	0.772	0.769
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.645	1.655	1.653	1.623	1.600	1.575	1.571
Feb	1.296	1.324	1.311	1.293	1.279	1.264	1.251
Mar	1.245	1.278	1.238	1.262	1.222	1.199	1.180
Apr	1.109	1.108	1.093	1.117	1.103	1.071	1.047
May	1.181	1.172	1.211	1.226	1.169	1.152	1.146
Jun	1.143	1.146	1.173	1.184	1.138	1.116	1.128
Jul	1.081	1.076	1.101	1.166	1.091	1.077	1.080
Aug	1.090	1.115	1.121	1.177	1.137	1.113	1.087
Sep	1.077	1.124	1.11	1.135	1.117	1.107	1.078
Oct	1.124	1.154	1.163	1.149	1.149	1.159	1.125
Nov	1.078	1.078	1.102	1.081	1.051	1.041	1.038
Dec	1.157	1.152	1.194	1.174	1.169	1.160	1.137
Revenue (One Million Dollars)	**11.85**	**11.98**	**12.03**	**12.19**	**11.87**	**11.70**	**11.55**

Table 3.6. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of Imported Frozen Flounder from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the Average Market Shares from 1991 to 2005, One Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.443	0.448	0.449	0.458	0.465	0.445	0.458	0.466
Feb	0.641	0.626	0.632	0.616	0.608	0.524	0.566	0.598
Mar	1.069	1.261	1.137	0.988	1.012	0.941	1.022	1.057
Apr	1.285	1.118	1.084	1.200	1.081	1.101	1.183	1.212
May	1.026	1.018	1.144	1.077	1.087	1.019	1.171	1.185
Jun	0.803	0.815	0.89	0.965	0.779	0.996	0.867	0.838
Jul	0.981	0.914	0.955	1.003	1.086	1.336	1.276	0.994
Aug	0.875	0.912	1.025	0.920	1.026	1.116	0.901	0.885
Sep	0.832	0.817	0.737	0.856	0.861	0.749	0.776	0.743
Oct	0.843	0.912	0.781	0.799	0.812	0.650	0.697	0.796
Nov	0.597	0.552	0.541	0.538	0.565	0.502	0.502	0.544
Dec	0.777	0.779	0.797	0.751	0.789	0.790	0.753	0.852
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.669	1.52	1.508	1.463	1.517	1.374	1.253	1.412
Feb	1.336	1.261	1.239	1.277	1.372	1.493	1.310	1.320
Mar	1.309	1.149	1.218	1.35	1.349	1.372	1.280	1.278
Apr	1.204	1.304	1.336	1.231	1.362	1.290	1.218	1.221
May	1.247	1.215	1.112	1.160	1.173	1.181	1.070	1.085
Jun	1.102	1.062	1.013	0.980	1.110	0.957	1.003	1.041
Jul	1.071	1.086	1.052	1.022	1.001	0.914	0.921	1.025
Aug	1.154	1.084	1.014	1.075	1.030	0.963	1.058	1.101
Sep	1.119	1.086	1.177	1.050	1.073	1.112	1.077	1.164
Oct	1.211	1.07	1.232	1.201	1.225	1.481	1.339	1.200
Nov	1.124	1.096	1.165	1.181	1.174	1.232	1.203	1.104
Dec	1.237	1.177	1.149	1.220	1.193	1.111	1.162	1.080
Revenue (One Million Dollars)	**12.35**	**11.85**	**11.89**	**11.89**	**12.18**	**11.85**	**11.56**	**11.77**

Table 3.6. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of Imported Frozen Flounder from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the Average Market Shares from 1991 to 2005, One Constraint Scenario

Monthly Landings of Summer Flounder (One Million Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.425	0.403	0.45	0.433	0.485	0.466	0.562
Feb	0.553	0.572	0.564	0.577	0.626	0.614	0.696
Mar	1.126	1.051	1.043	1.056	1.316	1.245	1.172
Apr	1.319	1.206	1.068	1.355	1.249	1.464	1.287
May	1.271	1.068	1.156	1.298	1.353	1.445	1.041
Jun	0.918	0.876	0.944	0.912	0.794	0.737	0.815
Jul	1.011	0.905	1.048	0.891	0.821	0.754	0.835
Aug	0.885	1.103	0.91	0.848	0.732	0.754	0.797
Sep	0.714	0.919	0.796	0.749	0.683	0.655	0.676
Oct	0.755	0.816	0.919	0.817	0.802	0.772	0.812
Nov	0.488	0.504	0.535	0.506	0.545	0.525	0.628
Dec	0.707	0.750	0.739	0.730	0.764	0.741	0.849
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.411	1.639	1.479	1.454	1.416	1.420	1.330
Feb	1.297	1.291	1.419	1.277	1.309	1.278	1.284
Mar	1.187	1.255	1.287	1.252	1.135	1.154	1.247
Apr	1.128	1.202	1.348	1.121	1.211	1.095	1.220
May	1.018	1.137	1.099	1.018	1.028	0.993	1.257
Jun	0.973	0.999	0.985	0.984	1.092	1.133	1.111
Jul	0.980	1.056	0.996	1.069	1.206	1.289	1.245
Aug	1.056	0.966	1.077	1.105	1.331	1.266	1.280
Sep	1.134	0.979	1.095	1.112	1.300	1.328	1.390
Oct	1.172	1.107	1.05	1.108	1.231	1.243	1.299
Nov	1.121	1.187	1.154	1.104	1.242	1.255	1.128
Dec	1.225	1.169	1.232	1.207	1.224	1.234	1.170
Revenue (One Million Dollars)	**11.36**	**11.56**	**11.84**	**11.49**	**12.22**	**12.09**	**12.64**

Table 3.7. Averages and Standard Deviations of Maximized Annual Revenues from Substitute Quantities Combination, One Constraint Scenario

	All Three Substitutes, 91-05	Atlantic, 91-05	Winter, 91-05	Imported Frozen Founder, 91-05
Average (One Million Dollars)	10.75	11.05	11.87	11.90
Standard Deviation (One Million Dollars)	0.49	0.52	0.21	0.35

3.4. Fisherman Estimate Scenarios

3.4.1. Estimates from Fisherman Surveys

Commercial summer flounder fishermen frequently catch fish in the ocean off one state, but land the fish at a port of another state. So, in section three, the model meets only one constraint. The constraint is that the total annual landings cannot be greater than the federal quota. There isn't a constraint on the monthly landings. In fact, the catch in any month is affected by factors such as weather, migration and movement of summer flounder. For example, in some months when summer flounder migrate they tend not to school. Fish that are spread out and not concentrated into schools are too expensive to catch. Fishermen understand such seasonal fluctuations and don't expect equal landing levels in all months. They believe that a major percentage of the quota could be caught in January and February. Conversely, in other months like May and August flounder movement reduces the possibility of commercial catches. So, a more realistic scenario will take into account that there are monthly constraints on landings in any month. The information for this type of constraint was acquired from three fishermen with many years of experience in fishing summer flounder. They were asked to estimate what percentage of the quota could be caught in each month of the year. The first two sets of estimates are from fishermen A and B. The third set of estimate is the average of all three fishermen estimates rounded to the nearest 5 per cent. The three scenarios using their estimates are called *Fisherman A*, *B* and *Average* estimate scenario. These estimates are imposed as upper bounds of landing quantities of summer flounder in solving the optimization model. These estimates are displayed in Table 3.8.

Table 3.8. Fishermen Estimates on Percentages of the Total Quota Can Be Caught in Each Month (Source: Fishermen Survey)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fisherman A	75%	80%	80%	50%	5%	20%	20%	5%	25%	30%	40%	50%
Fisherman B	80%	80%	60%	40%	0%	20%	20%	0%	25%	30%	40%	60%
Average Survey	75%	75%	65%	40%	5%	15%	15%	5%	20%	25%	35%	50%

The three sets of estimates are very close. In most months, the differences between the estimated percentages are not more than 5%. The largest difference occurs in estimates in March. *Fisherman A*'s estimate is 80%, while those of *Fisherman B* and the average are 60% and 65% respectively. In December, *Fisherman B*'s estimate is 60%, while those of *Fisherman A* and the three-fisherman average are both 50%. Another thing deserving attention is that *Fisherman B*'s estimates in May and August are 0%. *Fisherman A* and the three-fisherman average estimates are both 5% in these two months.

Table 3.9. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Substitutes' Quantities at 2005 level and the Average Market Shares from 1991 to 2005, One Constraint Scenario vs. Three Sets of Fishermen Estimates

Monthly Landings of Summer Flounder (One Million Pounds)				
	One Constraint	Fisherman A (Average)	Fisherman B	Not Extreme
Jan	0.443	0.498	0.629	0.543
Feb	0.641	0.730	0.954	0.807
Mar	1.069	1.176	1.416	1.261
Apr	1.285	1.398	1.641	1.486
May	1.026	0.509	0	0.153
Jun	0.803	0.878	1.041	0.937
Jul	0.981	1.087	1.317	1.170
Aug	0.875	0.509	0	0.153
Sep	0.832	0.933	1.165	1.015
Oct	0.843	0.939	1.161	1.018
Nov	0.597	0.672	0.846	0.734
Dec	0.777	0.843	0	0.895
Monthly Prices of Summer Flounder ($/Pound)				
	One Constraint	Fisherman A (Average)	Fisherman B	Not Extreme
Jan	1.669	1.572	1.398	1.503
Feb	1.336	1.268	1.144	1.219
Mar	1.309	1.261	1.172	1.226
Apr	1.204	1.170	1.106	1.145
May	1.247	1.578	0	2.167
Jun	1.102	1.074	1.022	1.054
Jul	1.071	1.043	0.99	1.023
Aug	1.154	1.353	0	1.801
Sep	1.119	1.082	1.014	1.056
Oct	1.211	1.167	1.085	1.135
Nov	1.124	1.085	1.014	1.058
Dec	1.237	1.201	0	1.175
Revenue (One Million Dollars)	**12.35**	**12.24**	**11.11**	**11.89**

To maximize the annual revenue with monthly constraints, twelve constraints are added into the maximization problem discussed in section three. The twelve constraints are

(3.17) $\exp\left(lfsq_i\right) \le \rho_i \times Quota$,

where: ρ_i is the percentages from fisherman surveys and $i = \{1, 2, ..., 12\}$. In solving the problem, the average market shares from 1991 to 2005 are used.

The results of the optimization models are listed in Table 3.9. The values in the columns titled *One Constraint* are landing quantities and prices of a model where no restrictions are placed on the monthly landings of summer flounder. The columns labeled *Fisherman A* and *B* are solutions for models where restrictions are placed on the potential monthly landings based on the fishermen's estimates. The maximum revenue and the related landing quantities and prices of the *Average* estimate are the same as those of *Fisherman A*, so they are displayed in a same column. The results in Table 3.9 indicate that the maximum revenues for *Fisherman A* and *Average* scenarios are \$12.24 million and that for *Fisherman B* is \$11.11 million.

3.4.2. Sensitivity Analyses on Substitute Quantities for *Average* Scenarios

There are three substitutes for summer flounder in the model, Atlantic, winter, and imported frozen flounder. Similar to the work in 3.3, sensitivity analyses of the effect of the three substitutes' quantities on maximum revenues are calculated for the *Average* and *Not Extreme* estimate scenarios. In the *Average* estimate scenario, the maximum revenue is the most sensitive to the monthly landing of imported frozen flounder with a standard deviation at \$0.49 million and the least sensitive to the monthly landing of winter flounder with a standard deviation at $0.30 million. The detailed results for the *Average* scenario are contained in Tables 3.10 to 3.13.

Table 3.10. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Atlantic Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Average Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.498	0.581	0.573	0.578	0.607	0.719	0.658	0.750
Feb	0.730	0.837	0.958	0.951	1.046	1.012	0.953	1.021
Mar	1.176	1.086	0.995	1.005	1.045	1.051	1.019	1.032
Apr	1.398	1.328	1.214	0.919	0.975	1.049	1.004	0.851
May	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Jun	0.878	0.909	0.885	1.005	0.939	0.930	0.897	0.919
Jul	1.087	1.026	1.058	1.098	1.069	1.046	1.053	1.071
Aug	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Sep	0.933	0.873	0.969	1.037	1.049	1.038	1.059	0.986
Oct	0.939	0.986	0.902	0.952	0.932	0.854	1.031	0.934
Nov	0.672	0.707	0.744	0.806	0.766	0.726	0.755	0.817
Dec	0.843	0.820	0.857	0.803	0.725	0.729	0.725	0.774
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.572	1.481	1.370	1.256	1.233	1.274	1.322	1.318
Feb	1.268	1.202	1.131	1.050	1.037	1.047	1.086	1.081
Mar	1.261	1.208	1.151	1.098	1.085	1.094	1.121	1.115
Apr	1.170	1.126	1.077	1.020	1.012	1.022	1.041	1.029
May	1.578	1.726	1.466	1.344	1.255	1.271	1.265	1.219
Jun	1.074	1.046	1.018	0.986	0.993	0.995	1.006	1.000
Jul	1.043	1.012	0.982	0.954	0.953	0.960	0.967	0.963
Aug	1.353	1.280	1.250	1.241	1.228	1.215	1.255	1.232
Sep	1.082	1.051	1.013	0.977	0.968	0.973	0.990	0.989
Oct	1.167	1.125	1.082	1.037	1.026	1.035	1.054	1.051
Nov	1.085	1.049	1.011	0.972	0.965	0.973	0.990	0.983
Dec	1.201	1.165	1.127	1.091	1.084	1.090	1.109	1.103
Revenue (One Million Dollars)	**12.24**	**11.92**	**11.32**	**10.78**	**10.67**	**10.79**	**10.98**	**10.93**

Table 3.10. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of Atlantic Flounder from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the Average Market Shares from 1991 to 2005, Average Estimate Scenario

Monthly Landings of Summer Flounder (One Million Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.687	0.687	0.688	0.638	0.651	0.712	0.693
Feb	0.953	1.019	1.062	1.030	1.027	1.038	1.107
Mar	1.076	1.128	1.075	1.212	1.017	1.011	1.356
Apr	0.878	0.958	0.920	0.915	0.935	0.897	0.989
May	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Jun	0.911	0.916	0.912	0.931	0.962	0.968	0.886
Jul	1.080	1.034	1.035	1.048	1.093	1.094	0.987
Aug	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Sep	0.962	0.991	1.003	1.028	1.053	1.011	0.917
Oct	0.922	0.866	0.854	0.855	0.896	0.891	0.778
Nov	0.815	0.759	0.757	0.746	0.767	0.746	0.729
Dec	0.872	0.797	0.849	0.751	0.753	0.785	0.712
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.294	1.284	1.283	1.253	1.213	1.221	1.326
Feb	1.061	1.059	1.061	1.043	1.011	1.008	1.093
Mar	1.107	1.104	1.102	1.096	1.069	1.066	1.131
Apr	1.023	1.023	1.021	1.013	0.999	0.996	1.040
May	1.237	1.218	1.214	1.213	1.210	1.210	1.230
Jun	1.001	0.999	1.004	0.995	0.988	0.994	1.010
Jul	0.958	0.963	0.962	0.960	0.948	0.955	0.976
Aug	1.219	1.213	1.211	1.205	1.203	1.199	1.211
Sep	0.986	0.981	0.979	0.972	0.959	0.962	0.998
Oct	1.044	1.041	1.041	1.032	1.015	1.014	1.060
Nov	0.976	0.976	0.975	0.969	0.955	0.955	0.991
Dec	1.094	1.092	1.090	1.086	1.073	1.070	1.109
Revenue (One Million Dollars)	**10.85**	**10.82**	**10.81**	**10.71**	**10.52**	**10.55**	**11.04**

Table 3.11. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Winter Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Average Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.498	0.550	0.556	0.556	0.554	0.551	0.497	0.494
Feb	0.730	0.822	0.820	0.824	0.819	0.825	0.732	0.729
Mar	1.176	1.305	1.312	1.310	1.316	1.309	1.199	1.194
Apr	1.398	1.563	1.551	1.569	1.571	1.571	1.440	1.433
May	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Jun	0.878	0.928	0.942	0.936	0.938	0.928	0.850	0.853
Jul	1.087	1.178	1.196	1.168	1.175	1.164	1.072	1.082
Aug	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Sep	0.933	1.039	1.024	1.035	1.037	1.047	0.938	0.937
Oct	0.939	1.034	1.034	1.032	1.033	1.043	0.940	0.935
Nov	0.672	0.735	0.720	0.724	0.711	0.717	0.643	0.655
Dec	0.843	0.000	0.000	0.000	0.000	0.000	0.844	0.842
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.572	1.489	1.449	1.444	1.452	1.489	1.584	1.590
Feb	1.268	1.185	1.181	1.140	1.168	1.182	1.246	1.249
Mar	1.261	1.163	1.144	1.144	1.130	1.158	1.198	1.203
Apr	1.170	1.030	1.045	1.008	1.000	1.021	1.046	1.058
May	1.578	1.438	1.390	1.421	1.417	1.435	1.483	1.485
Jun	1.074	1.074	1.053	1.059	1.056	1.076	1.127	1.117
Jul	1.043	1.024	0.994	1.032	1.021	1.047	1.078	1.048
Aug	1.353	1.309	1.316	1.356	1.258	1.254	1.305	1.280
Sep	1.082	1.030	1.051	1.029	1.023	1.019	1.067	1.063
Oct	1.167	1.100	1.080	1.077	1.042	1.051	1.120	1.100
Nov	1.085	1.025	0.992	1.007	0.981	0.977	1.018	1.044
Dec	1.201	0.000	0.000	0.000	0.000	0.000	1.127	1.130
Revenue (One Million Dollars)	**12.24**	**11.48**	**11.36**	**11.34**	**11.21**	**11.36**	**11.83**	**11.80**

Table 3.11. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Winter Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Average Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.499	0.556	0.499	0.506	0.504	0.505	0.505
Feb	0.730	0.826	0.730	0.738	0.731	0.727	0.726
Mar	1.194	1.296	1.198	1.197	1.203	1.206	1.210
Apr	1.427	1.560	1.433	1.435	1.430	1.433	1.437
May	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Jun	0.854	0.919	0.840	0.838	0.857	0.867	0.860
Jul	1.080	1.184	1.073	1.052	1.077	1.079	1.078
Aug	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Sep	0.943	1.030	0.935	0.933	0.932	0.932	0.940
Oct	0.933	1.046	0.938	0.945	0.937	0.935	0.931
Nov	0.654	0.737	0.665	0.663	0.641	0.631	0.630
Dec	0.842	0.000	0.843	0.848	0.843	0.840	0.839
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.554	1.479	1.559	1.530	1.511	1.490	1.488
Feb	1.232	1.200	1.246	1.227	1.216	1.203	1.192
Mar	1.201	1.191	1.194	1.216	1.179	1.158	1.141
Apr	1.080	1.051	1.064	1.086	1.074	1.044	1.021
May	1.461	1.445	1.516	1.545	1.440	1.408	1.398
Jun	1.115	1.092	1.144	1.154	1.110	1.090	1.102
Jul	1.054	1.024	1.072	1.135	1.063	1.051	1.054
Aug	1.256	1.295	1.303	1.392	1.329	1.292	1.252
Sep	1.044	1.056	1.074	1.098	1.082	1.073	1.046
Oct	1.085	1.076	1.122	1.108	1.109	1.120	1.087
Nov	1.043	1.011	1.066	1.045	1.017	1.009	1.006
Dec	1.125	0.000	1.160	1.141	1.137	1.130	1.108
Revenue (One Million Dollars)	**11.75**	**11.57**	**11.93**	**12.08**	**11.77**	**11.61**	**11.46**

Table 3.12. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Imported Frozen Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Average Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.498	0.560	0.598	0.525	0.545	0.647	0.678	0.634
Feb	0.730	0.812	0.896	0.714	0.709	0.685	0.748	0.800
Mar	1.176	1.564	1.444	1.083	1.131	1.164	1.245	1.305
Apr	1.398	1.270	1.267	1.304	1.178	1.317	1.395	1.441
May	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Jun	0.878	0.967	1.136	1.096	0.869	1.387	1.096	1.044
Jul	1.087	1.087	1.210	1.132	1.263	1.526	1.526	1.273
Aug	0.509	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Sep	0.933	1.018	0.926	0.989	1.009	1.004	1.014	0.932
Oct	0.939	1.186	0.986	0.895	0.926	0.786	0.835	1.011
Nov	0.672	0.691	0.690	0.600	0.645	0.638	0.618	0.714
Dec	0.843	0.000	0.000	0.818	0.879	0.000	0.000	0.000
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.572	1.375	1.328	1.379	1.410	1.195	1.108	1.247
Feb	1.268	1.153	1.105	1.212	1.289	1.330	1.188	1.186
Mar	1.261	1.080	1.127	1.302	1.290	1.263	1.196	1.185
Apr	1.170	1.243	1.257	1.197	1.315	1.210	1.156	1.152
May	1.578	1.498	1.343	1.416	1.457	1.420	1.249	1.299
Jun	1.074	1.019	0.964	0.959	1.077	0.913	0.963	0.992
Jul	1.043	1.039	0.996	0.997	0.971	0.903	0.905	0.973
Aug	1.353	1.237	1.143	1.225	1.182	1.047	1.179	1.255
Sep	1.082	1.028	1.098	1.017	1.031	1.033	1.014	1.088
Oct	1.167	1.006	1.139	1.159	1.171	1.364	1.251	1.113
Nov	1.085	1.035	1.083	1.142	1.126	1.140	1.129	1.029
Dec	1.201	0.000	0.000	1.186	1.152	0.000	0.000	0.000
Revenue (One Million Dollars)	**12.24**	**11.44**	**11.46**	**11.78**	**12.06**	**11.48**	**11.18**	**11.39**

Table 3.12. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Imported Frozen Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Average Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.553	0.501	0.517	0.562	0.576	0.562	0.651
Feb	0.718	0.750	0.639	0.766	0.739	0.745	0.794
Mar	1.394	1.275	1.157	1.286	1.535	1.467	1.292
Apr	1.574	1.414	1.150	1.634	1.382	1.680	1.391
May	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Jun	1.170	1.097	1.077	1.158	0.888	0.826	0.885
Jul	1.311	1.111	1.203	1.090	0.906	0.831	0.898
Aug	0.509	0.509	0.509	0.509	0.509	0.509	0.509
Sep	0.882	1.326	0.909	0.943	0.759	0.732	0.729
Oct	0.940	1.063	1.093	1.067	0.912	0.887	0.889
Nov	0.613	0.617	0.604	0.649	0.613	0.596	0.701
Dec	0.000	0.000	0.806	0.000	0.846	0.827	0.924
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.274	1.477	1.392	1.306	1.318	1.314	1.253
Feb	1.187	1.177	1.347	1.161	1.230	1.194	1.220
Mar	1.116	1.177	1.240	1.173	1.086	1.101	1.203
Apr	1.078	1.144	1.310	1.068	1.171	1.057	1.187
May	1.153	1.354	1.318	1.165	1.222	1.143	1.619
Jun	0.940	0.961	0.963	0.947	1.060	1.097	1.084
Jul	0.943	1.011	0.971	1.021	1.167	1.244	1.211
Aug	1.169	1.051	1.223	1.241	1.530	1.447	1.516
Sep	1.074	0.927	1.060	1.049	1.249	1.272	1.345
Oct	1.103	1.038	1.012	1.038	1.178	1.186	1.252
Nov	1.059	1.118	1.115	1.039	1.192	1.200	1.090
Dec	0.000	0.000	1.196	0.000	1.182	1.189	1.137
Revenue (One Million Dollars)	**10.96**	**11.17**	**11.73**	**11.08**	**12.11**	**11.96**	**12.54**

Table 3.13. Averages and Standard Deviations of Maximized Annual Revenues from Substitute Quantities Combination, *Average Estimate Scenario*

	Atlantic, 91-05	Winter, 91-05	Imported Frozen, 91-05
Average (One Million Dollars)	11.64	11.65	11.00
Standard Deviation (One Million Dollars)	0.47	0.30	0.49

3.4.3. Not Extreme Scenario and the Sensitivity Analyses

Since in *Fisherman B* estimate, the landings are zero in May and August. They are *extreme* cases. In order to check how non-landing in May and August will change the optimized revenue, a *Not Extreme* scenario is generated. In the *Not Extreme* scenario, the percentages in May and August are changed to 1.5%, the lowest percentage to the nearest 0.5 per cent that resulted in nonzero landings in these two months, and percentages in other months are the same as those from *Fisherman B*'s estimates. The maximized revenue, and optimized landings for the *Not Extreme* case are displayed in Table 3.9. The optimized revenue is $11.89 million. This is less than the maximum revenue of $12.24 million for *Fisherman A (Average)* scenario, but higher than that *Fisherman B* scenario at $11.11 million. The results show that no landings in May and August will decrease the maximized revenue. In the *Not Extreme* estimate scenario, the maximized revenue is the most sensitive to the monthly landing of Atlantic flounder with a standard deviation at $0.45 million, and least sensitive to the monthly landing of winter flounder with a standard deviation at $0.19 million. The detailed results for *Not Extreme* scenario are contained in from Tables 3.14 to 3.17.

Table 3.14. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Atlantic Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Not Extreme Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.543	0.635	0.627	0.636	0.668	0.79	0.72	0.821
Feb	0.807	0.926	1.063	1.061	1.168	1.13	1.06	1.135
Mar	1.261	1.166	1.067	1.078	1.121	1.128	1.093	1.106
Apr	1.486	1.412	1.29	0.977	1.036	1.114	1.068	0.905
May	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Jun	0.937	0.969	0.941	1.066	0.994	0.985	0.951	0.975
Jul	1.17	1.103	1.135	1.174	1.141	1.116	1.126	1.145
Aug	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Sep	1.015	0.948	1.05	1.121	1.134	1.123	1.147	1.066
Oct	1.018	1.067	0.975	1.028	1.006	0.923	1.114	1.009
Nov	0.734	0.771	0.809	0.876	0.831	0.788	0.82	0.887
Dec	0.895	0.87	0.908	0.849	0.767	0.771	0.767	0.819
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.503	1.417	1.312	1.203	1.181	1.220	1.266	1.263
Feb	1.219	1.156	1.088	1.010	0.998	1.008	1.045	1.040
Mar	1.226	1.176	1.120	1.069	1.056	1.065	1.092	1.086
Apr	1.145	1.102	1.054	0.999	0.991	1.001	1.020	1.008
May	2.167	2.353	2.027	1.878	1.774	1.792	1.785	1.739
Jun	1.054	1.026	0.999	0.968	0.974	0.976	0.988	0.982
Jul	1.023	0.992	0.963	0.936	0.935	0.941	0.948	0.944
Aug	1.801	1.727	1.699	1.691	1.681	1.673	1.703	1.684
Sep	1.056	1.026	0.988	0.954	0.945	0.950	0.966	0.966
Oct	1.135	1.094	1.053	1.010	0.999	1.008	1.027	1.023
Nov	1.058	1.023	0.986	0.948	0.941	0.949	0.965	0.959
Dec	1.175	1.140	1.103	1.068	1.061	1.067	1.085	1.079
Revenue (One Million Dollars)	**11.89**	**11.53**	**11.00**	**10.49**	**10.40**	**10.53**	**10.72**	**10.69**

Table 3.14. (Cont.) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Atlantic Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Not Extreme Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.754	0.754	0.755	0.701	0.716	0.783	0.76
Feb	1.063	1.136	1.183	1.149	1.151	1.164	1.23
Mar	1.154	1.209	1.153	1.299	1.091	1.085	1.453
Apr	0.934	1.018	0.978	0.973	0.994	0.953	1.052
May	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Jun	0.965	0.971	0.966	0.986	1.017	1.023	0.939
Jul	1.155	1.105	1.106	1.119	1.166	1.166	1.055
Aug	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Sep	1.04	1.071	1.084	1.111	1.138	1.091	0.992
Oct	0.996	0.935	0.922	0.924	0.967	0.963	0.841
Nov	0.885	0.824	0.822	0.81	0.831	0.809	0.792
Dec	0.922	0.843	0.898	0.794	0.796	0.83	0.753
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.239	1.230	1.229	1.200	1.162	1.169	1.269
Feb	1.021	1.019	1.021	1.004	0.973	0.970	1.052
Mar	1.078	1.075	1.073	1.067	1.041	1.038	1.101
Apr	1.002	1.002	1.000	0.992	0.979	0.976	1.019
May	1.756	1.738	1.736	1.736	1.739	1.739	1.749
Jun	0.983	0.981	0.985	0.977	0.970	0.975	0.991
Jul	0.940	0.944	0.944	0.942	0.929	0.936	0.957
Aug	1.675	1.672	1.670	1.669	1.669	1.675	1.670
Sep	0.962	0.957	0.956	0.949	0.937	0.939	0.974
Oct	1.016	1.014	1.013	1.005	0.989	0.987	1.032
Nov	0.952	0.952	0.951	0.945	0.932	0.931	0.966
Dec	1.071	1.069	1.068	1.063	1.051	1.047	1.086
Revenue (One Million Dollars)	**10.60**	**10.58**	**10.58**	**10.48**	**10.29**	**10.31**	**10.81**

Table 3.15. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Atlantic Flounder* from 1991 to 1997, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Not Extreme Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.543	0.538	0.544	0.544	0.542	0.539	0.539	0.536
Feb	0.807	0.801	0.799	0.802	0.799	0.804	0.806	0.802
Mar	1.261	1.280	1.288	1.286	1.292	1.285	1.288	1.282
Apr	1.486	1.535	1.524	1.540	1.543	1.542	1.547	1.536
May	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Jun	0.937	0.913	0.928	0.922	0.924	0.914	0.898	0.903
Jul	1.170	1.157	1.174	1.149	1.155	1.144	1.143	1.159
Aug	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Sep	1.015	1.017	1.003	1.013	1.016	1.024	1.018	1.017
Oct	1.018	1.013	1.012	1.011	1.011	1.019	1.020	1.018
Nov	0.734	0.718	0.702	0.707	0.694	0.699	0.708	0.716
Dec	0.895	0.895	0.893	0.892	0.891	0.896	0.899	0.896
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.503	1.506	1.464	1.459	1.467	1.505	1.520	1.526
Feb	1.219	1.197	1.192	1.150	1.179	1.194	1.201	1.204
Mar	1.226	1.171	1.151	1.152	1.137	1.166	1.167	1.172
Apr	1.145	1.035	1.050	1.013	1.005	1.026	1.026	1.038
May	2.167	1.877	1.779	1.842	1.835	1.870	1.968	1.971
Jun	1.054	1.080	1.058	1.064	1.061	1.081	1.107	1.097
Jul	1.023	1.029	0.999	1.037	1.025	1.052	1.058	1.029
Aug	1.801	1.704	1.720	1.807	1.596	1.587	1.696	1.642
Sep	1.056	1.036	1.057	1.035	1.029	1.025	1.043	1.039
Oct	1.135	1.107	1.087	1.084	1.049	1.058	1.091	1.072
Nov	1.058	1.031	0.999	1.013	0.987	0.983	0.994	1.020
Dec	1.175	1.102	1.104	1.084	1.073	1.091	1.104	1.107
Revenue (One Million Dollars)	**11.89**	**11.48**	**11.37**	**11.32**	**11.19**	**11.36**	**11.51**	**11.49**

Table 3.15. (Cont) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Atlantic Flounder* from 1991 to 1997, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Not Extreme Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.542	0.543	0.543	0.552	0.549	0.549	0.548
Feb	0.804	0.804	0.806	0.817	0.807	0.803	0.801
Mar	1.282	1.272	1.290	1.287	1.295	1.299	1.304
Apr	1.524	1.532	1.537	1.536	1.529	1.537	1.544
May	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Jun	0.903	0.904	0.888	0.886	0.907	0.918	0.908
Jul	1.155	1.162	1.147	1.117	1.150	1.153	1.148
Aug	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Sep	1.027	1.008	1.015	1.010	1.008	1.008	1.019
Oct	1.018	1.022	1.020	1.031	1.019	1.012	1.011
Nov	0.715	0.719	0.725	0.727	0.705	0.695	0.692
Dec	0.896	0.899	0.896	0.904	0.896	0.893	0.891
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.491	1.496	1.494	1.465	1.450	1.431	1.431
Feb	1.188	1.213	1.200	1.181	1.173	1.161	1.151
Mar	1.171	1.200	1.163	1.184	1.149	1.129	1.113
Apr	1.059	1.056	1.043	1.064	1.053	1.025	1.003
May	1.923	1.890	2.036	2.097	1.879	1.816	1.796
Jun	1.096	1.098	1.123	1.132	1.091	1.071	1.084
Jul	1.034	1.029	1.052	1.113	1.043	1.032	1.036
Aug	1.592	1.674	1.692	1.886	1.748	1.668	1.583
Sep	1.020	1.063	1.049	1.072	1.058	1.049	1.024
Oct	1.058	1.084	1.093	1.078	1.080	1.092	1.061
Nov	1.018	1.017	1.040	1.019	0.993	0.986	0.984
Dec	1.103	1.097	1.136	1.117	1.114	1.108	1.087
Revenue (One Million Dollars)	**11.44**	**11.56**	**11.61**	**11.73**	**11.45**	**11.30**	**11.16**

Table 3.16. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Imported Frozen Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Not Extreme Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	0.543	0.547	0.578	0.576	0.599	0.577	0.622	0.604
Feb	0.807	0.791	0.860	0.789	0.779	0.632	0.706	0.764
Mar	1.261	1.531	1.406	1.151	1.208	1.093	1.196	1.263
Apr	1.486	1.254	1.245	1.376	1.238	1.250	1.350	1.404
May	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Jun	0.937	0.951	1.106	1.189	0.925	1.264	1.047	1.010
Jul	1.170	1.068	1.179	1.224	1.377	1.850	1.714	1.227
Aug	0.153	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Sep	1.015	0.997	0.903	1.086	1.107	0.922	0.961	0.900
Oct	1.018	1.156	0.960	0.965	1.000	0.743	0.805	0.974
Nov	0.734	0.676	0.671	0.645	0.697	0.595	0.593	0.684
Dec	0.895	0.896	0.957	0.865	0.935	0.942	0.873	1.036
Monthly Prices of Summer Flounder ($/Pound)								
	2005	2004	2003	2002	2001	2000	1999	1998
Jan	1.503	1.389	1.347	1.326	1.351	1.246	1.137	1.271
Feb	1.219	1.164	1.120	1.171	1.242	1.377	1.211	1.206
Mar	1.226	1.087	1.137	1.271	1.256	1.294	1.212	1.199
Apr	1.145	1.249	1.265	1.175	1.288	1.233	1.168	1.163
May	2.167	1.973	1.620	1.782	1.877	1.792	1.423	1.526
Jun	1.054	1.023	0.969	0.945	1.058	0.926	0.971	0.999
Jul	1.023	1.044	1.003	0.981	0.953	0.886	0.894	0.981
Aug	1.801	1.516	1.302	1.487	1.390	1.101	1.383	1.560
Sep	1.056	1.033	1.106	0.996	1.007	1.056	1.026	1.099
Oct	1.135	1.012	1.149	1.131	1.141	1.397	1.269	1.126
Nov	1.058	1.041	1.092	1.116	1.099	1.166	1.144	1.040
Dec	1.175	1.127	1.089	1.164	1.128	1.063	1.115	1.029
Revenue (One Million Dollars)	**11.89**	**11.45**	**11.49**	**11.49**	**11.76**	**11.50**	**11.23**	**11.38**

Table 3.16. (Cont) Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Monthly Quantities of *Imported Frozen Flounder* from 1991 to 2005, Other Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *Not Extreme Estimate Scenario*

Monthly Landings of Summer Flounder (One Million Pounds)							
	1997	1996	1995	1994	1993	1992	1991
Jan	0.545	0.492	0.564	0.551	0.641	0.625	0.735
Feb	0.708	0.734	0.692	0.751	0.819	0.830	0.884
Mar	1.379	1.255	1.234	1.269	1.683	1.603	1.395
Apr	1.560	1.396	1.204	1.614	1.467	1.807	1.478
May	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Jun	1.156	1.078	1.164	1.141	0.948	0.877	0.944
Jul	1.294	1.094	1.306	1.076	0.960	0.875	0.950
Aug	0.153	0.153	0.153	0.153	0.153	0.153	0.153
Sep	0.872	1.289	0.985	0.929	0.808	0.778	0.773
Oct	0.929	1.041	1.217	1.048	0.985	0.956	0.956
Nov	0.606	0.607	0.650	0.638	0.658	0.639	0.764
Dec	0.816	0.878	0.851	0.850	0.898	0.877	0.987
Monthly Prices of Summer Flounder ($/Pound)							
	1997	1996	1995	1994	1993	1992	1991
Jan	1.280	1.490	1.340	1.315	1.261	1.259	1.194
Feb	1.193	1.185	1.304	1.169	1.185	1.151	1.171
Mar	1.119	1.183	1.212	1.178	1.057	1.073	1.169
Apr	1.081	1.149	1.286	1.071	1.147	1.037	1.160
May	1.232	1.645	1.567	1.255	1.367	1.213	2.268
Jun	0.942	0.964	0.950	0.949	1.041	1.078	1.063
Jul	0.945	1.014	0.957	1.025	1.144	1.220	1.185
Aug	1.360	1.109	1.484	1.524	2.278	2.047	2.238
Sep	1.077	0.931	1.038	1.054	1.219	1.243	1.310
Oct	1.106	1.043	0.988	1.042	1.147	1.156	1.217
Nov	1.062	1.123	1.091	1.043	1.163	1.172	1.061
Dec	1.171	1.117	1.175	1.151	1.158	1.165	1.112
Revenue (One Million Dollars)	**11.05**	**11.21**	**11.46**	**11.15**	**11.80**	**11.69**	**12.16**

Table 3.17. Averages and Standard Deviations of Maximized Annual Revenues from Substitute Quantities Combination, *Not Extreme Estimate Scenario*

	Atlantic, 91-05	Winter, 91-05	Imported Frozen, 91-05
Average (One Million Dollars)	10.73	11.46	11.51
Standard Deviation (One Million Dollars)	0.45	0.19	0.30

Lastly, in Appendix C, three extensions are generated from *Fisherman B* scenario. In these three extensions, different restrictions are imposed on the optimization model to deal with non-landing in May and August. These extensions are solved and the results contained in Table C1 in Appendix C. They show that the optimization model is stable and consistent in different extensions and it might be a partial verification that the revenue maximization model is operating correctly.

3.5. Optimum Landing Pattern and Monthly Real Price

Three different scenarios, *One Constraint*, *Average*, and *Not Extreme*, are compared in this section. The sensitivities of the optimized revenues to the substitutes' quantities are calculated for these three scenarios. In sensitivity analysis of each scenario, there are three categories representing the different substitutes, Atlantic, winter, and imported frozen flounder. In each category, there are fifteen optimizations representing years from 1991 to 2005. The average optimized monthly landings and real prices of summer flounder are calculated for all three categories in each scenario. So, in each of the three scenarios, *One Constraint*, *Average*, and *Not Extreme*, there are three sets of average monthly landings and real prices representing different substitutes. Then the average monthly landings and real prices of each scenario are the average of the three categories of substitutes.

Using the monthly landing averages in each scenario, the corresponding percentages to the total annul quota in 2007 are calculated and listed in Table 3.18. Table 3.18 also contains one column of historical percentages of the average monthly landings from 1991 to 2005, and another column of the fisherman average estimate percentages. The landing percentages in Table 3.18 are plotted in Figure 3.1, but the fisherman average estimate percentage is excluded. The historical percentage of the average monthly landing is the highest at 18% in January and falls to the level around 4% to 5% in the months from April to August. Then it reaches another high level of 12% in October. However, the *Average* and *Not Extreme* estimate scenarios indicate that the January percentage of landings should be around 6%. The percentages of landings increase to the high levels around 12% to 13% and 9% to 11% in the periods of March to April and June to July respectively in these two scenarios. Between these two high levels, there is a low in May for both scenarios. Another low percentages for these two scenarios occur in August. This August low is followed by a jump to 10% in September for both scenarios. The January percentage in the *One Constraint* scenario is 5%. This is very close to those of the other two scenarios but different from the historical one, which is 18%. The *One Constraint* scenario also has two peaks occurring in April and July. But its fluctuation is not as prominent as those of the other two scenarios. These three scenarios are similar in the fluctuation pattern. They all contain two cycles, January to July and August to December. The difference is that the cyclical fluctuations are evident for the *Average* and *Not Extreme* estimate scenarios, but not that prominent for *One Constraint* scenario. This result can be because that the *One Constraint* scenario doesn't have monthly constraints, which are included in the other two scenarios. The historical percentage of the average monthly landing just has one cycle over a whole year. The low level covers four months and from April to August, when landing percentages are around 4% to 5%. The left most three columns of percentages in Table 3.18 are acquired from the corresponding optimization scenarios.

Table 3.18. Monthly Percentages of the Total Annual Landing in Different Scenarios of Landing Summer Flounder

	Average Survey	Historical Average, 1991-2005	One Constraint	Average	Not Extreme
Jan	75%	18%	5%	6%	6%
Feb	75%	12%	7%	8%	9%
Mar	65%	8%	10%	12%	12%
Apr	40%	4%	11%	13%	13%
May	5%	4%	10%	5%	2%
Jun	15%	4%	8%	9%	10%
Jul	15%	5%	10%	11%	11%
Aug	5%	5%	9%	5%	2%
Sep	20%	10%	8%	10%	10%
Oct	25%	12%	8%	9%	10%
Nov	35%	10%	6%	7%	7%
Dec	50%	7%	7%	6%	9%

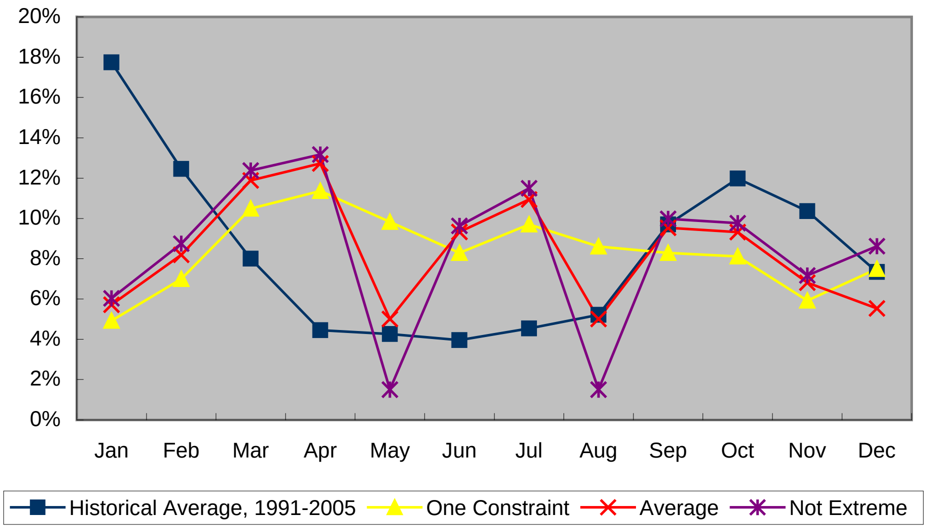

Figure 3.1. Monthly Percentages of the Total Annual Landing in Different Scenarios of Landing Summer Flounder

The average real prices of the historical data from 1991 to 2005 and the three scenarios are listed in Table 3.19 and plotted in Figure 3.2. Similar to the average landings, it is found that *Average* and *Not Extreme* estimate scenario prices fluctuated cyclically. The high levels of prices for the *Average* scenario occur in January ($1.39/Pound), May ($1.37/Pound), and August ($1.26/Pound). The high levels of prices of the *Not Extreme* scenario occur in May ($1.80/Pound) and August ($1.65/Pound). The cyclical fluctuation of the *One Constraint* scenario price is mild. Lastly, the historical average monthly real price has a high period covering six months from March to August at around $1.20/Pound.

Table 3.19. Monthly Real Price in Different Scenarios of Landing Summer Flounder ($/Pound)

	Average, 1991-2005	One Constraint	Average	Not Extreme
Jan	0.878	1.49	1.39	1.35
Feb	1.031	1.25	1.17	1.14
Mar	1.236	1.21	1.16	1.14
Apr	1.264	1.13	1.09	1.08
May	1.218	1.14	1.37	1.80
Jun	1.217	1.06	1.03	1.02
Jul	1.216	1.05	1.02	1.00
Aug	1.199	1.09	1.26	1.65
Sep	0.977	1.09	1.05	1.03
Oct	0.958	1.15	1.10	1.08
Nov	0.898	1.08	1.04	1.02
Dec	1.012	1.16	0.78	1.11

The two figures imply that both the monthly landing percentages and real prices of all the optimization models are cyclical. The fluctuations in the scenarios with monthly constraints, suggested by experienced fishermen, contain two cycles. The monthly landing percentages and real prices of the historical data have one cycle and contain continuous low landing percentage months from April to August and high real prices months from March to August of the year.

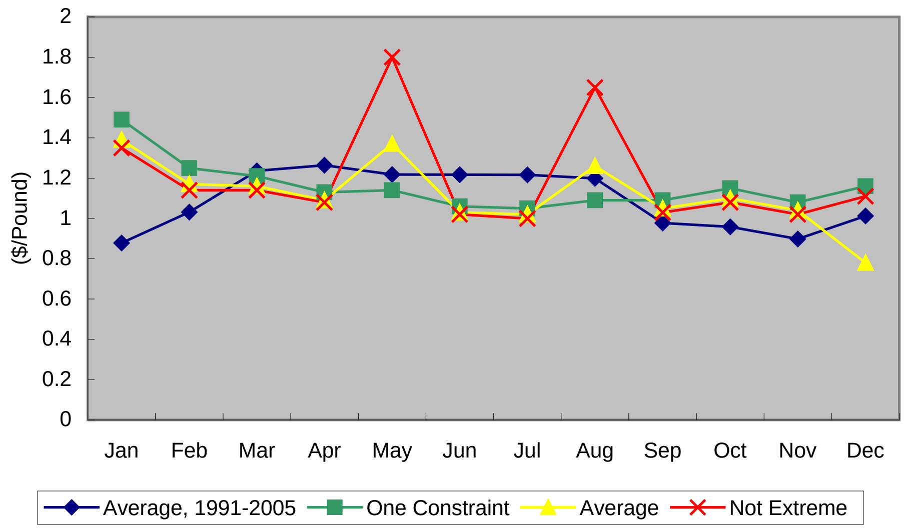

Figure 3.2. Monthly Real Price in Different Scenarios of Landing Summer Flounder

3.6. Revenues of Historical Annual Landings Obtained with the Optimization Model

To study how the optimization model affects annual revenue, the historical annual landing for each year from 1991 to 2005 is put into the model as federal quotas. Models to maximize the annual revenue given these quotas are solved. The maximized revenues are compared with the annual revenue calculated from historical data. In the comparison, maximum revenues for all three scenarios, *One Constraint*, *Average*, and *Not Extreme* are evaluated. The revenues from all three scenarios are higher than those derived from the historical data for all years through 1991 to 2005. Among the three scenarios, it is not surprising that the *One Constraint* scenario has the highest revenues, since the other two have twelve monthly quota constraints. The total increased revenue over the historical revenue earned by applying the *One Constraint* scenario is $46.60 million over the fifteen years. The total extra revenues earned through the *Average* and *Not Extreme* scenarios are $44.73 million and $36.54 million respectively over the fifteen years. The comparison is contained in Table 3.20.

Table 3.20. Monthly Real Price in Different Scenarios of Landing Summer Flounder ($ Million)

	Scenario			
	Historical Average, 1991-2005	One Constraint	Average	Not Extreme
1991	17.06	20.86	20.74	20.16
1992	18.62	22.14	22.02	21.42
1993	17.01	20.47	20.34	19.78
1994	21.31	23.96	23.83	23.18
1995	23.02	26.20	26.06	25.35
1996	17.81	20.01	19.88	19.33
1997	15.00	18.63	18.49	17.96
1998	16.28	18.79	18.66	18.13
1999	14.50	17.53	17.40	16.90
2000	14.88	18.35	18.22	17.71
2001	13.07	16.03	15.91	15.47
2002	14.64	17.12	17.02	16.55
2003	14.66	16.99	16.88	16.41
2004	17.35	19.26	19.16	18.64
2005	16.60	22.05	21.93	21.33
Total	251.79	298.39	296.52	288.33
Revenue Gains		46.60	44.73	36.54

3.7. Conclusions

In the second stage of the project, the revenue maximization problem is solved for various scenarios. In each scenario, sensitivity analyses of the optimized revenue to the monthly substitute quantities from 1991 to 2005 are evaluated. In all scenarios, the optimized revenue of landings of summer flounder is the least sensitive to the winter flounder landings.

The optimized monthly landings and real prices of summer flounder in all scenarios cycle through the year. There are two cycles in a year. For the scenario with monthly constraints, the cyclical fluctuation is much more evident than that without monthly constraints. However, the average landings and real prices from the historical data through 1991 to 2005 contain just one cycle.

The monthly constraints on landings are from fisherman surveys estimates and their average. In the survey, some fishermen suggest no catch of summer flounder in May and August. The optimization results indicate that no catch of summer flounder in these two months will decrease the total annual revenue, and lead to no catch in December also.

To study the revenue change with the application of the optimization model, the historical total annual landings are put into the model as quota constraints. The total annual revenues of the scenarios 1991 through 2005 exceed the historical revenue. The highest total increase over historical revenue is $46.60 million and the lowest one is $36.54 million over the 15 years.

The monthly real price function of landing summer flounder for 2007 is estimated using the data from 1991 to 2004. The 2005 data is used to evaluate forecasting performance of different models. The optimization models to maximize annual revenue in 2007 are solved using 2005 quantities and average market shares from 1991 to 2005. Projections with this analytical framework will improve if the demand model is estimated annually and incorporated into the optimization model as is commonly done with most policy analysis models.

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Chapter Four

Price Impacts on China's Soybean Imports: A Production System Approach

4.1 Background

4.1.1 China's Production and Consumption of Domestically Produced Soybeans

China is the fourth largest soybean producer in the world (USDA 2007). Fluctuations in China's soybean production stem from changes in its planting area. In 2006, the economic returns from soybeans were less than corn. Thus, in 2007, China's soybean production declined in Heilongjiang Province, China's largest soybean producing area and referred to as the soybean production basis of the country. Figure 4.1 shows that with a reduction in China's soybean planting area in 2007, its annual production in that year dropped to 14 MMT (million metric tons), from a historical high at 17.4 MMT in 2004.

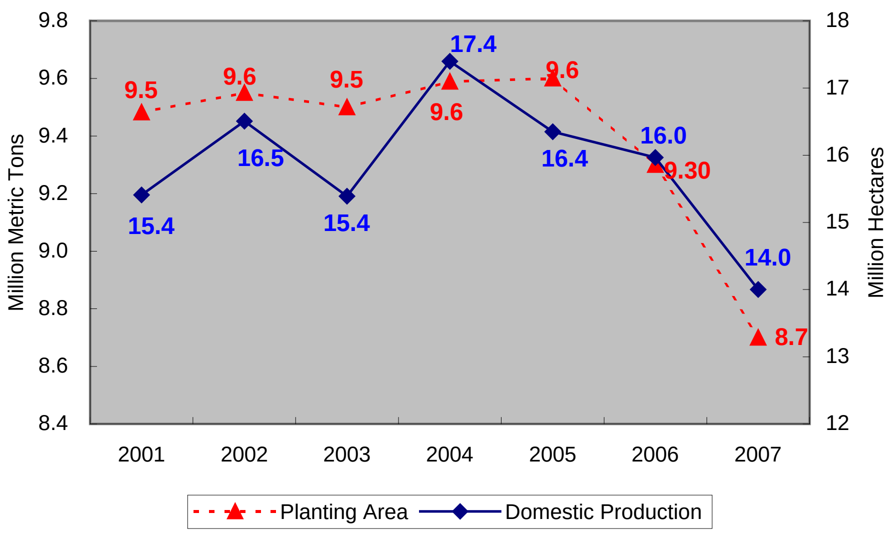

Figure 4.1. China's Soybean Planting Area and Domestic Production of Soybeans, 2001-2007. (Source: USDA, FAS, 2004d, 2005d, 2006c, 2007a, and 2008a)

Soybeans are native to China. All soybeans planted in China are non-genetically modified (non-GM) soybeans. Most of China's domestically planted soybeans are used to produce soybean food, like tofu and soymilk, the most important vegetable protein sources for Chinese consumers. In 2007, soybean food consumption accounted for 61 percent of China's domestic soybean production and reached 8.5 MMT (Figure 4.2). In contrast, the share of food consumption soybeans was just 41 percent in 2001. This rapid increase in the share of food consumption soybeans was attributed to Chinese consumers' preference for vegetable protein and the steady growth of their purchasing power (USDA, FAS, 2007a).

The remainder of China's domestic non-GM soybeans are used to: (1) crush consumption: produce soybean meal and oil, (2) feed consumption: feed animals in backyard and small operations, (3) export to other Asian markets, primarily Japan and South Korea, who produce soybean food from non-GM soybeans, and (4) be stored in national stockpiles (Figure 4.2). In 2007, 25 percent of China's domestically produced soybeans were crushed to produce soybean meal and oil; around 12 percent were directly used as feed in small and backyard operations; and the remaining two percent were exported and stored in national stockpiles.

China formally became a member of the World Trade Organization (WTO) on December 11, 2001 (WTO, 2001). From 2001 to 2007, China's total consumption of soybeans increased 72 percent, from 28.3 MMT to 48.7 MMT (Figure 4.3). In 2002, China's soybean imports surpassed its domestic production for the first time, and have continued increase. Additionally, the share of imports in China's total soybean consumption increased from 37 percent to 72 percent across the same time period.

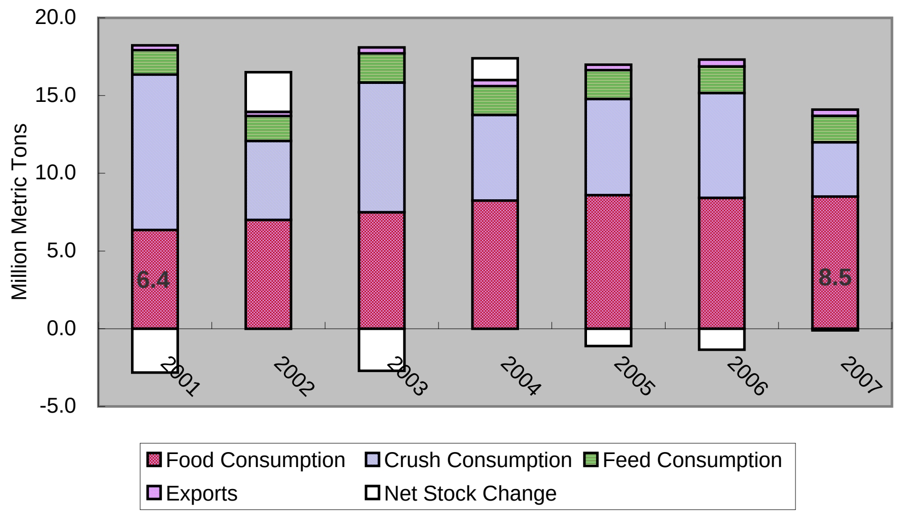

Figure 4.2: Distribution of China's Domestically Produced Soybeans, 2001-2007. (Source: USDA, FAS, 2004d, 2005d, 2006c, 2007a, and 2008a)

4.1.2 China's Soybean Imports

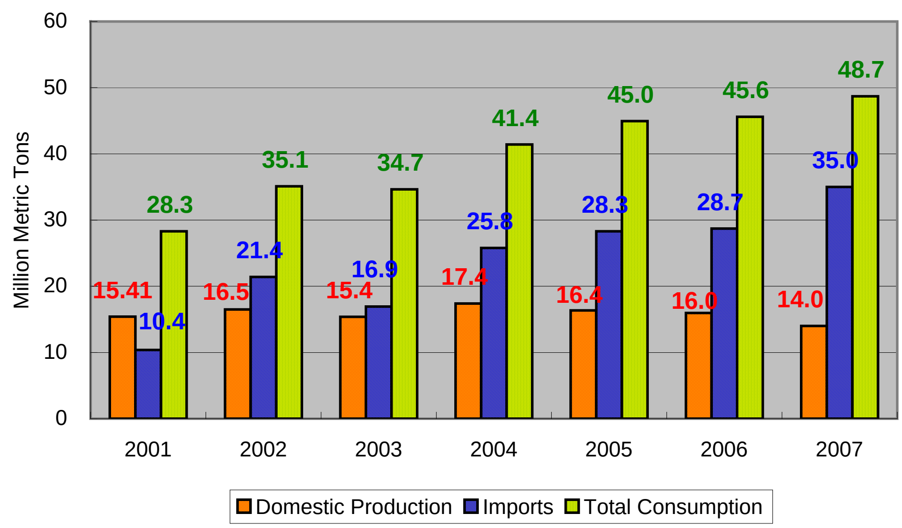

Figure 4.3. China's Domestic Soybean Production, Imports, and Total Consumption, 2001- 2007. (Source: USDA, FAS, 2004d, 2005d, 2006c, 2007a, 2008a)

The USDA predicted that China's domestic consumption of soybeans would reach 51.1 MMT in 2008 (USDA, FAS, 2008a). However, China's domestic soybean production has never been greater than 18 MMT. China's domestically planted soybeans are only enough to satisfy its demand for soybean food, but much less than its demand for soybean oil and meal. In order to meet this demand, China needs to import large quantities of soybeans each year.

China’s soybean imports increased 116 percent from 13.3 MMT in 2000/01 to 28.7 MMT in 2006/07 (marketing year, from October to September). Across the same time period, the share of China’s soybean imports grew from 25 percent to 42 percent of global soybean trade (Figure 4.4). According to USDA (2007), global soybean imports will increase another 27 MMT in the next decade, and China will account for 78 percent of this total increase. In other words, USDA predicts that China’s annual soybean imports will increase 21 MMT by 2016.

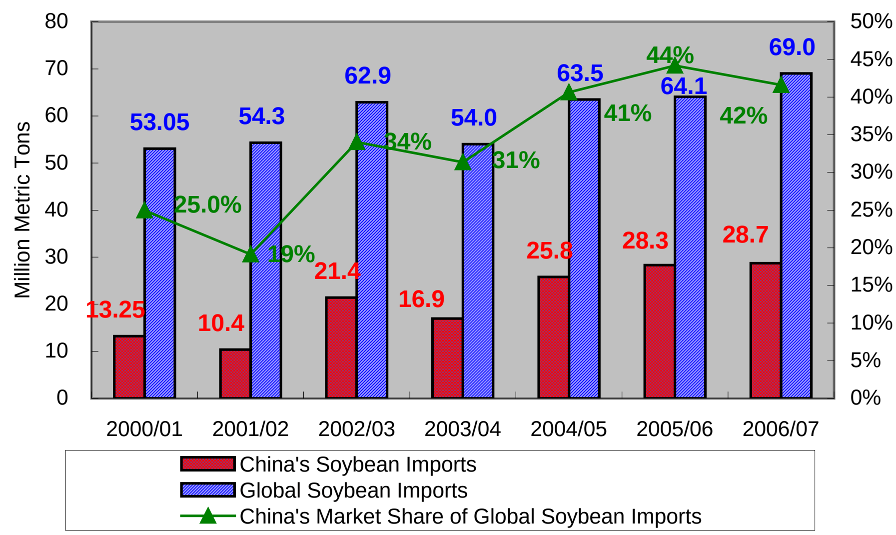

Figure 4.4. China’s and World Annual Total Soybean Imports, Marketing Year 2000/01 — 2006/07. (Source: USDA, FAS, 2004d, 2005d, 2006c, 2007a, 2008a)

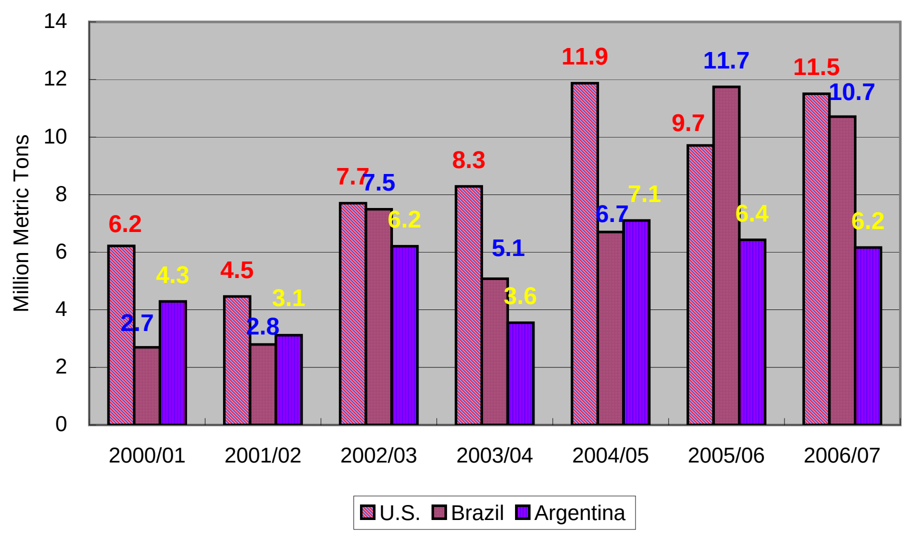

Figure 4.5. China's Soybean Imports from U.S. Brazil and Argentina 2000/01-2006/07. (Source: USDA, FAS, 2004d, 2005d, 2006c, 2007a, 2008a)

Since 2000, soybeans have been the U.S. leading agricultural exports for bulk commodities, exceeding corn and wheat (USDA-FAS, PS&D, 2008). Today, China is the largest soybean importer in the world and the largest market for U.S. soybean exports. China's imports accounted for 40 percent of U.S. soybean exports in 2006/07. Brazil and Argentina are China's other two major soybean suppliers. The U.S., Brazil, and Argentina consistently account for 99 percent of China's total soybean imports. The U.S. was the largest soybean supplier for China from 2000/01 to 2006/07, except for 2005/06, when Brazil took the lead (Figure 4.5).

4.1.3 China's Marketing System of Soybean Products

Currently, GM soybeans account for more than 90 percent of global soybean production. GM soybeans cannot be used to produce soybean food in China. China imports GM soybeans to produce soybean meal and oil. China's government implements a series of policies and regulations on protecting its non-GM soybean seeds and managing its GM soybean imports from the global markets (Marchant et al. 2002 and

Marchant et al. 2005). The large quantity of China's soybean imports is attributed to the country's fast growing demand for soybean meal and oil (Figure 4.6).

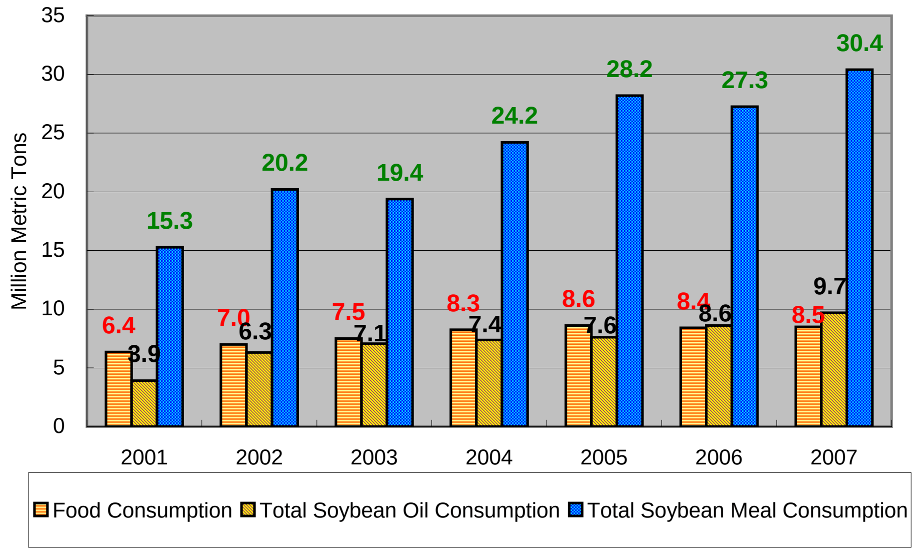

Figure 4.6. China's Soybean Product Consumption: Food from Domestically Planted Soybeans, and Total Soybean Oil and Meal from Soybean Imports and Domestically Planted Soybeans 2001-2007. (Source: USDA, FAS, 2004d, 2005d, 2006c, 2007a, 2008a)

Soybean meal and oil are joint products obtained from crushing raw soybeans. The crushing ratios for soybean oil and meal are stable. Every 100 MMT of soybeans can produce 79 MMT of soybean meal and 18 MMT of soybean oil (Figure 4.7). In addition to producing soybean meal and oil from soybean imports, every year, China needs to import soybean oil to meet its domestic consumption of vegetable oil (Figure 4.8).

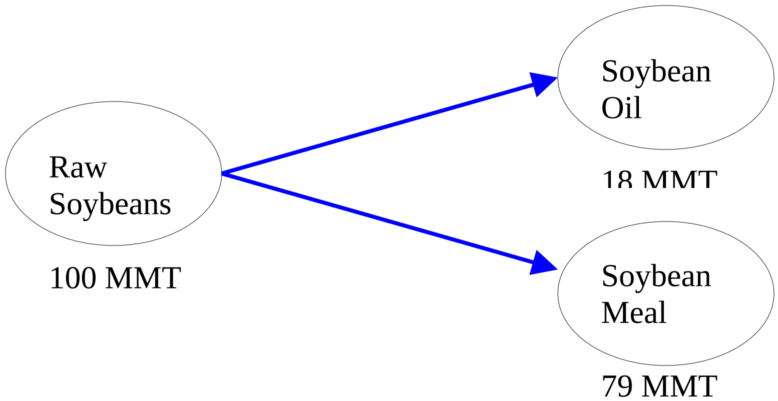

Figure 4.7 Joint Production and Crushing Ratios for Soybean Oil and Meal from Raw Soybeans. (Source: USDA, FAS, 2008a)

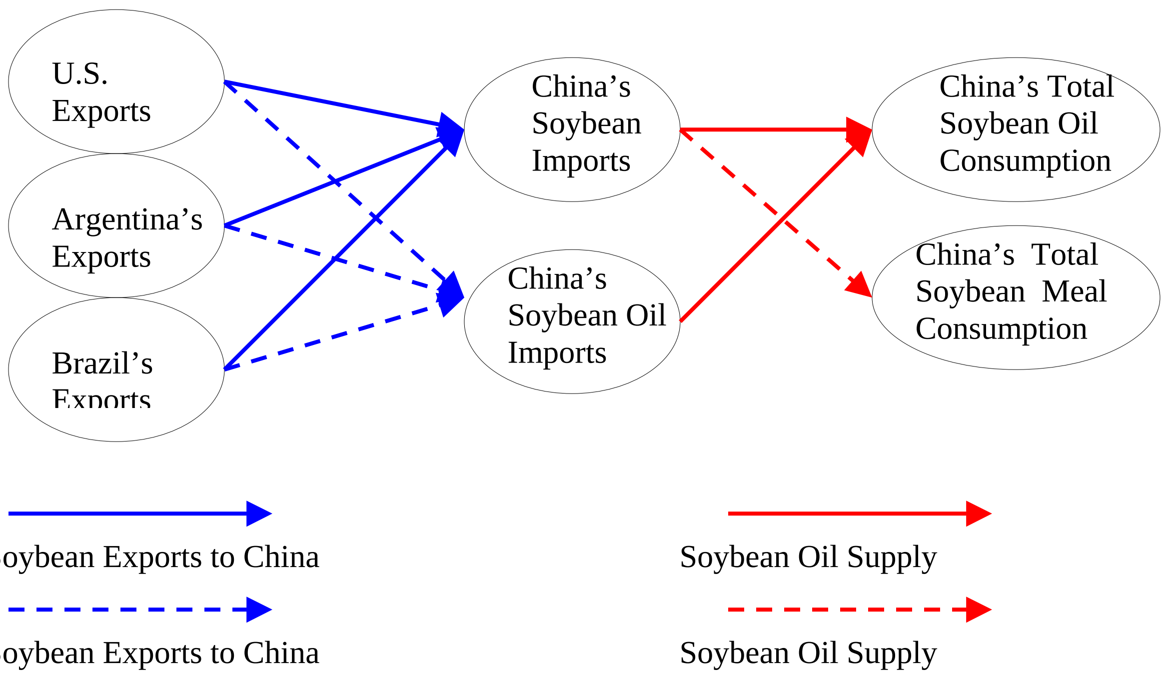

Figure 4.8. China's Soybean Import Marketing System. (Source: USDA, FAS, 2008a)

Soybean Oil

China's total soybean oil consumption increased from 3.9 MMT to 9.7 MMT from 2001 to 2007 (Figure 4.6). Soybean oil produced from domestically planted soybeans was approximately 0.6 MMT in 2007. China's total soybean oil consumption was 16 times its soybean oil crushed from domestically planted soybeans. Out of this 9.7 MMT of soybean oil consumption, 6.3 MMT were crushed from imported soybeans. In addition, China also imported 2.8 MMT of soybean oil from Argentina, Brazil, and the U.S. in 2007, increasing from 0.4 MMT in 2002. If this 2.8 MMT of soybean oil were crushed domestically, China would need additional 15.6 MMT of soybeans. This equals almost half of China's soybean imports in 2007.

Soybean Meal

From 2001 to 2007, China's soybean meal consumption almost doubled increasing from 15.3 MMT to 30.5 MMT (Figure 4.6). Of this, 27.7 MMT were crushed from China's soybean imports and 2.8 MMT crushed from China's domestically planted soybeans. Thus, China primarily processes soybean imports to obtain soybean meal.

Crushing Capacity

China's soybean crushing capacity was estimated to be 80 MMT, with half of it unused in 2007 (USDA, FAS, 2008a). The Chinese government implements a tariff policy discouraging soybean oil imports. The import tariff rate for soybean oil is nine percent, while the rate is three percent for raw soybeans. This unused crushing capacity and a high soybean oil import tariff rate should encourage China's bulk soybean imports and discourage its soybean oil imports.

In 2007, China's soybean meal crushed from soybean imports and its domestically produced soybeans was enough to meet its domestic consumption. For soybean oil, if China did not import soybean oil directly, an additional 15.6 MMT of soybeans would have to be imported to meet China's demand for soybean oil. Due to the joint production of soybean products, these 15.6 MMT of soybeans would produce an additional 12.2 MMT of soybean meal. Soybean meal is very high in protein content and difficult to store.

This storage problem may discourage China from importing an additional 15.6 MMT of soybeans to meet its domestic soybean oil demand. Therefore, the above analysis implies that China's soybean imports is determined by its domestic derived demand for soybean meal and, in addition to producing soybean oil from crushing soybean imports, China needs to import soybean oil directly to meet its domestic demand for soybean oil.

4.2 Research Purpose and Hypothesis

The purpose of this paper is to estimate both international market price elasticities and China's domestic price elasticities of China's soybean imports. U.S. agribusinesses can use results from this research to evaluate how China's soybean imports from different source countries will change when either international market prices or China's domestic market prices change. A differential production model is used in this paper. This model is derived from a two-stage profit maximization model in producer theory. China's soybean imports are treated as inputs in this model with soybean meal and oil being treated as outputs. Conditional and unconditional import price elasticities are calculated to determine how changes in China's soybean import price from one source country affect China's soybean imports from this country and other countries. The difference between conditional and unconditional import price elasticities is that the former holds total imports constant, while the latter includes the effects of changes in the total import expenditure.

China's soybean marketing system implies that China's soybean imports are enough to meet the domestic soybean meal demand, but not enough to meet its soybean oil demand, which requires extra soybean oil imports. Therefore, the following hypothesis of China's soybean crushing industry will be tested:

China's domestic soybean meal price rather than soybean oil price affects its soybean imports.

4.3. Data

The monthly values and quantities of China's soybeans imports were collected from World Trade Atlas. Prices are calculated by dividing values by the corresponding quantities. China's domestic monthly prices for soybeans, soybean meal and oil were obtained in USDA, FAS (2004d, 2005d, 2006c, 2007a, 2008a, and 2008e). All prices are in terms of U.S. dollars, December 2007 adjusted by the Producer Price Index (PPI) for soybeans provided on the website of the Bureau of Labor Statistics, the U.S. Department of Labor.

This paper focuses on the period after China became a formal member of World Trade Organization (WTO) on December 11, 2001. However, because from February to May 2002, neither Argentina nor Brazil exported soybeans to China, the model uses data from January 2003 to December 2007.

4.4. Literature Review

Sarwar and Anderson (1990) set up a simultaneous supply and demand equation model to investigate U.S. soybean exports to different regions. Sarwar and Anderson's approach is from the perspective of the U.S., the exporting country. The estimated short-term own-price elasticity of export demand is -0.63 for developed countries, -0.42 for Asian countries, and -3.62 for Latin American countries.

Song et al. (2009) apply a simultaneous equation system to analyze competitiveness of China's three soybean suppliers by investigating the relationship between China's soybean imports and soybean stocks in exporting areas. The paper concludes that China's soybean imports from the U.S. and South America are seasonally complementary to each other and South American countries' soybean exports to China can be a complete substitute for the U.S. exports, while U.S. soybean exports are just a partial substitute for South American countries' exports to China.

For the soybean crushing industry, soybeans are raw products, from which two joint products – soybean meal and oil – are produced. Piggott and Wohlgenant (2002) develop an equation system containing both domestic and foreign markets for soybeans and soybean products. This system is based on Houck's (1964) model for joint products. Piggott and Wohlgenant (2002) conclude that taking account of trade in soybean oil and meal has a more profound impact on the responsiveness of total soybean demand than only taking into account soybeans. Therefore, research in this thesis takes into account soybean meal and oil prices in China's domestic markets.

Davis and Jensen (1994) point out that although in a two-stage utility maximization model imported agricultural commodities are treated as final goods; in fact, most imported agricultural commodities are inputs. For example, China imports soybeans to produce soybean meal and oil, and China's consumers do not consume imported soybeans directly. This conceptual misspecification leads to biased estimation and inference. Davis and Jensen (1994) propose a two-stage profit maximization model based on producer theory to overcome this limitation. This producer theory approach consists of two stages: profit maximization and cost minimization, and encompass virtues of conditional demand systems derived from consumer theory. In the profit maximization stage and can be used to estimate unconditional elasticities and structural parameters.

The differential production model is a member of the two-stage profit maximization family. This model is proposed in Laitinen and Theil (1978), Laitinen (1980) and Theil (1980). A total-import expenditure equation and import-demand system are derived in this two-stage profit maximization procedure. In recent years, this method has been applied to topics like Hong Kong's cheese imports (Washington and Kilmer 2002), EU's fish imports (Muhammad 2007) and U.S. lamb imports (Muhammad et. al 2007). This differential production method has been extended to analyses of international trade policies such as subsidy reduction and trade agreement (Muhammad et. al 2008 and Muhammad et al. 2009). In this paper, the differential production model is adopted to analyze the effects of international and China's domestic prices on China's soybean imports.

4.5. Model Specification

Differential production model is based on producer theory, however this paper focuses on China's national soybean imports rather than a single soybean crushing firm's behavior. A question arises whether it is appropriate to apply this differential production model derived from producer theory to a topic at an aggregate industrial level. Washington and Kilmer (2002) answer this question by comparing optimizing behavior of consumers and firms. For consumers, the aggregate demand functions satisfies all of the properties of an individual demand function as long as consumer preferences and wealth effects are identical across all different consumers, otherwise, even a slight difference in preference will lead to violation of properties. However, for price taking firms, the aggregate behavior to maximize profit is identical to the sum of each profit-maximizing firm. Therefore, different from utility maximizing model, the properties of the demand and supply functions for each individual firm will be the same as that when aggregate data are applied.

The differential production model contains two stages, profit maximization and cost minimization. In this model, China soybean imports are considered as intermediate inputs rather than final products in models derived from consumer's utility functions. Soybean meal and oil are outputs in this model.

4.5.1 Stage One: Cost Minimization

In this stage, an input demand system, which will be estimated, is derived from solving a cost minimization problem in producer theory. Derivation of the input demand system is described below and based on Laitinen (1980).

A general cost minimization problem of a firm facing *n* inputs ($\underset{\sim}{x} = \left[x_i\right]' = \left[x_1, ..., x_n\right]'$) and *m* outputs ($\underset{\sim}{q} = \left[q_r\right]' = \left[q_1, ..., q_m\right]'$) is to

(4.1) $\underset{x_i}{Min} \sum_{i=1}^{n} w_i x_i$

subject to

(4.2) $h\left(\underset{\sim}{x}, \underset{\sim}{q}\right) = 0$ [1],

[1] $h\left(\underset{\sim}{x}, \underset{\sim}{q}\right) = \log\left[d\left(\underset{\sim}{x}, \underset{\sim}{q}\right)\right]$, where the output distance function is $d\left(\underset{\sim}{x}, \underset{\sim}{q}\right) = \overline{q}_r / q_r$ for each r.

where $\underset{\sim}{w} = [w_i]' = [w_1, ..., w_n]'$ is the input price vector and $h(\underset{\sim}{x}, \underset{\sim}{q}) = 0$ is a production function homogeneous of degree -1. Euler's theorem for a homogeneous function implies that

$$(4.3)\quad \sum_{r=1}^{m} \frac{\partial\left(h\left(\underset{\sim}{x}, \underset{\sim}{q}\right)\right)}{\partial(\log q_r)} = -1.$$

The Lagrangean function of this cost minimization problem is

$$(4.4)\quad L(\underset{\sim}{x}, \underset{\sim}{w}) = \sum_{i=1}^{n} w_i x_i - \rho h\left(\underset{\sim}{x}, \underset{\sim}{q}\right),$$

where ρ is the Lagrangean multiplier. The first order condition of this cost minimization problem is

$$(4.5)\quad \frac{\partial\left(L(\underset{\sim}{x}, \underset{\sim}{w})\right)}{\partial(\log x_i)} = w_i x_i - \rho \frac{\partial\left(h\left(\underset{\sim}{x}, \underset{\sim}{q}\right)\right)}{\partial(\log x_i)} = 0$$

and

$$(4.6)\quad w_i x_i = \rho \frac{\partial\left(h\left(\underset{\sim}{x}, \underset{\sim}{q}\right)\right)}{\partial(\log x_i)}.$$

The theoretical input demand system is described below and ultimately shown in equation (4.53), which is derived from equation (4.56). Equation (4.56) contains two terms $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial\left(\log \underset{\sim}{q}'\right)}$ and $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}$. Laitinen (1980) shows how to derive terms

$\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial\left(\log \underset{\sim}{q}'\right)}$ and $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}$ from a cost minimization problem.

An overview of this process follows. Lemma 4.1 and Lemma 4.2 differentiate equation (4.5) with respect to $\log q_r$ and $\log w_j$, respectively, and set up an equation system in matrix form, i.e. equation (4.24), for $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$ and $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}$. Similarly, Lemma 4.3 and Lemma 4.4 differentiate equation (4.2) with respect to $\log q_r$ and $\log w_j$, respectively, and set up another equation system in matrix form, i.e. equation (4.38), for $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$ and $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}$. Through combining common terms for equations (4.24) and (4.38), a new matrix equation (4.43) is set up and then both $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$ and $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}$ are solved in Lemma 4.5. In order to get a more easily estimated representation, Lemma 4.6 proposes another approach to calculate $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$ and this term is specified in equation (4.47). Finally, the input demand system, equation (4.53), is obtained through substituting equation (4.47) for $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$ and equation (4.38) for $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}$ into equation (4.56).

First, in order to obtain term $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$, equation (4.5) is differentiated with respect to $\log q_r$. Equation (4.7) in Lemma 4.1 is obtained after performing algebraic operations.

Lemma 4.1: Solve the cost minimization problem described in equations (4.1) and (4.2), and then it is derived that

(4.7) $\mathbf{F}^{-1}(\mathbf{F}-\gamma\mathbf{H})\mathbf{F}^{-1}\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')} - \underset{\sim}{\iota}\frac{\partial(\log \rho)}{\partial(\log \underset{\sim}{q}')} = \gamma\mathbf{F}^{-1}\mathbf{H}^{*}$, where $\mathbf{F}$ is an $n \times n$ diagonal matrix with the share of ith factor in total cost $C = \sum_{i=1}^{n} w_i x_i$,

(4.8) $f_i = w_i x_i / C$,

along the diagonal, $\underset{\sim}{\iota} = [1,...,1]'$ is a $n \times 1$ vector,

(4.9) $\mathbf{H} = \dfrac{\partial^2 h(\underset{\sim}{x}, \underset{\sim}{q})}{\partial(\log \underset{\sim}{x})\partial(\log \underset{\sim}{x}')}$,

and

(4.10) $\mathbf{H}^* = \dfrac{\partial^2 h(\underset{\sim}{x}, \underset{\sim}{q})}{\partial(\log \underset{\sim}{x})\partial(\log \underset{\sim}{q}')}$.

Proof:

Differentiate equation (4.5) with respect to $\log q_r$ and equation (4.11) is derived as follows

$$(4.11)\quad w_i x_i \frac{\partial(\log x_i)}{\partial(\log q_r)} - \rho \frac{\partial\left(h(\underset{\sim}{x}, \underset{\sim}{q})\right)}{\partial(\log x_i)} \frac{\partial(\log \rho)}{\partial(\log q_r)} - \rho \sum_{j=1}^{n} \frac{\partial^2\left(h(\underset{\sim}{x}, \underset{\sim}{q})\right)}{\partial(\log x_i)\partial(\log x_j)} \frac{\partial(\log x_j)}{\partial(\log q_r)} - \rho \frac{\partial^2\left(h(\underset{\sim}{x}, \underset{\sim}{q})\right)}{\partial(\log x_i)\partial(\log q_r)} = 0.$$

Substitute equation (4.6) into equation (4.8):

$$(4.12)\quad w_i x_i \frac{\partial(\log x_i)}{\partial(\log q_r)} - w_i x_i \frac{\partial(\log \rho)}{\partial(\log q_r)} - \rho \sum_{j=1}^{n} \frac{\partial^2\left(h(\underset{\sim}{x}, \underset{\sim}{q})\right)}{\partial(\log x_i)\partial(\log x_j)} \frac{\partial(\log x_j)}{\partial(\log q_r)} - \rho \frac{\partial^2\left(h(\underset{\sim}{x}, \underset{\sim}{q})\right)}{\partial(\log x_i)\partial(\log q_r)} = 0.$$

Divide both sides of equation (4.12) by the total cost $C = C(\underset{\sim}{q}, \underset{\sim}{w})$:

(4.13) $$\frac{w_i x_i}{C}\frac{\partial(\log x_i)}{\partial(\log q_r)}-\frac{w_i x_i}{C}\frac{\partial(\log \rho)}{\partial(\log q_r)}-\frac{\rho}{C}\sum_{j=1}^{n}\frac{\partial^2\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial(\log x_i)\partial\left(\log x_j\right)}\frac{\partial(\log x_j)}{\partial(\log q_r)}$$
$$-\frac{\rho}{C}\frac{\partial^2\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial(\log x_i)\partial(\log q_r)}=0.$$

Define

(4.14) $$\gamma=\frac{\rho}{C},$$

and substitute equations (4.8) and (4.14) into equation (4.13):

(4.15) $$f_i\frac{\partial(\log x_i)}{\partial(\log q_r)}-f_i\frac{\partial(\log \rho)}{\partial(\log q_r)}-\gamma\sum_{j=1}^{n}\frac{\partial^2\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial(\log x_i)\partial\left(\log x_j\right)}\frac{\partial(\log x_j)}{\partial(\log q_r)}$$
$$-\gamma\frac{\partial^2\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial(\log x_i)\partial(\log q_r)}=0.$$

The matrix form of equation (4.15) is

(4.16) $$\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial\left(\log \underset{\sim}{q}'\right)}-\mathbf{F}\underset{\sim}{\boldsymbol{\iota}}\frac{\partial(\log \rho)}{\partial\left(\log \underset{\sim}{q}'\right)}-\gamma\mathbf{H}\frac{\partial(\log \underset{\sim}{x})}{\partial\left(\log \underset{\sim}{q}'\right)}-\gamma\mathbf{H}^*=0.$$

Equation (4.16) can be rewritten as:

(4.17) $$\left(\mathbf{F}-\gamma\mathbf{H}\right)\frac{\partial(\log \underset{\sim}{x})}{\partial\left(\log \underset{\sim}{q}'\right)}-\mathbf{F}\underset{\sim}{\boldsymbol{\iota}}\frac{\partial(\log \rho)}{\partial\left(\log \underset{\sim}{q}'\right)}=\gamma\mathbf{H}^*.$$

Multiply both sides of equation (4.17) by $\mathbf{F}^{-1}$ and equation (4.7) is reached

(4.7) $$\mathbf{F}^{-1}\left(\mathbf{F}-\gamma\mathbf{H}\right)\mathbf{F}^{-1}\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial\left(\log \underset{\sim}{q}'\right)}-\underset{\sim}{\boldsymbol{\iota}}\frac{\partial(\log \rho)}{\partial\left(\log \underset{\sim}{q}'\right)}=\gamma\mathbf{F}^{-1}\mathbf{H}^*.$$ □

Now, term $\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}$ is obtained. In order to obtain term $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$, equation (4.5) is differentiated with respect to $\log w_j$. Equation (4.18) in Lemma 4.2 is obtained after performing algebraic operations.

Lemma 4.2: Solve the cost minimization problem described in equations (4.1) and (4.2), and then it is derived that

$$(4.18)\quad \mathbf{F}^{-1}\left(\mathbf{F}-\gamma\mathbf{H}\right)\mathbf{F}^{-1}\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)} - \underset{\sim}{\iota}\frac{\partial\left(\log \rho\right)}{\partial\left(\log \underset{\sim}{w}'\right)} = -\mathbf{I}\,.$$

Proof:

Differentiate equation (4.5) with respect to $\log w_j$ and equation (4.19) is derived as follows:

$$(4.19)\quad \delta_{ij}w_i x_i + w_i x_i\frac{\partial\left(\log x_i\right)}{\partial\left(\log w_j\right)} - \rho\frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)}\frac{\partial\left(\log \rho\right)}{\partial\left(\log w_j\right)}$$
$$-\rho\sum_{k=1}^{n}\frac{\partial^2\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)\partial\left(\log x_k\right)}\frac{\partial\left(\log x_k\right)}{\partial\left(\log q_j\right)} = 0,$$

where $\delta_{ij} = \begin{cases}1 & i=j\\ 0 & i\neq j\end{cases}$. Put (4.6) into (4.19):

$$(4.20)\quad \delta_{ij}w_i x_i + w_i x_i\frac{\partial\left(\log x_i\right)}{\partial\left(\log w_j\right)} - w_i x_i\frac{\partial\left(\log \rho\right)}{\partial\left(\log w_j\right)} - \rho\sum_{k=1}^{n}\frac{\partial^2\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)\partial\left(\log x_k\right)}\frac{\partial\left(\log x_k\right)}{\partial\left(\log q_j\right)} = 0$$

Devide both sides of equation (4.20) by the total cost *C*, and substitute (4.8) and (4.14) into (4.20). Equation (4.21) is derived as

$$(4.21)\quad \delta_{ij}f_i + f_i\frac{\partial\left(\log x_i\right)}{\partial\left(\log w_j\right)} - f_i\frac{\partial\left(\log \rho\right)}{\partial\left(\log w_j\right)} - \gamma\sum_{k=1}^{n}\frac{\partial^2\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)\partial\left(\log x_k\right)}\frac{\partial\left(\log x_k\right)}{\partial\left(\log q_j\right)} = 0\,.$$

Write equation (4.21) in the form of matrix:

$$(4.22)\ \mathbf{F}+\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}-\mathbf{F}\underset{\sim}{\iota}\frac{\partial(\log \rho)}{\partial(\log \underset{\sim}{w}')}-\gamma\mathbf{H}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}=0,$$

and

$$(4.23)\ (\mathbf{F}-\gamma\mathbf{H})\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}-\mathbf{F}\underset{\sim}{\iota}\frac{\partial(\log \rho)}{\partial(\log \underset{\sim}{w}')}=-\mathbf{F}.$$

Multiply both sides of (4.23) by $\mathbf{F}^{-1}$ and equation (4.18) is proven:

$$(4.18)\ \mathbf{F}^{-1}(\mathbf{F}-\gamma\mathbf{H})\mathbf{F}^{-1}\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}-\underset{\sim}{\iota}\frac{\partial(\log \rho)}{\partial(\log \underset{\sim}{w}')}=-\mathbf{I}. \qquad \square$$

Thus, terms $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$ and $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}$ have been specified in equations (4.7) and (4.18). These two equations are combined into a system below in equation (4.24).

$$(4.24)\ \left[\mathbf{F}^{-1}(\mathbf{F}-\gamma\mathbf{H})\mathbf{F}^{-1} \quad \underset{\sim}{\iota}\right]\begin{bmatrix}\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')} & \mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')} \\ -\frac{\partial(\log \rho)}{\partial(\log \underset{\sim}{q}')} & -\frac{\partial(\log \rho)}{\partial(\log \underset{\sim}{w}')}\end{bmatrix}=\left[\gamma\mathbf{F}^{-1}\mathbf{H}^{*} \quad -\mathbf{I}\right]$$

In order to solve for these two terms, another system containing them is developed in Lemma 4.3 and Lemma 4.4. These two systems will be combined in equation (4.43). Similar to Lemma 4.1, equation (4.2) is differentiated with respect to $\log q_r$ to obtain term $\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$.

Lemma 4.3: Solve the cost minimization problem described in equations (4.1) and (4.2), and then it is derived that

$$(4.25)\quad \underset{\sim}{\iota}'\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)} = \gamma \underset{\sim}{g}',$$

where $\underset{\sim}{g}$ is a vector containing the share of the *r*th product in total marginal cost,

$$(4.26)\quad g_r = \frac{q_r}{\rho}\frac{\partial C}{\partial q_r},$$

as its *r*th element.

Proof:

Differentiate equation (4.2) with respect to $\log q_r$

$$(4.27)\quad \sum_{i=1}^{n}\frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)}\frac{\partial\left(\log x_i\right)}{\partial\left(\log q_r\right)} + \frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log q_r\right)} = 0$$

Multiply both sides of equation (4.27) by γ

$$(4.28)\quad \sum_{i=1}^{n}\gamma\frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)}\frac{\partial\left(\log x_i\right)}{\partial\left(\log q_r\right)} + \gamma\frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log q_r\right)} = 0.$$

Derive equation (4.29) from equations (4.6) and (4.15):

$$(4.29)\quad \gamma\frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)} = \frac{w_i x_i}{C} = f_i.$$

Solve the cost minimization problem, and equation (4.30) is derived as:

$$(4.30)\quad g_r = -\frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log q_r\right)}.$$

Substitute equations (4.29) and (4.30) into equation (4.28):

$$(4.31)\quad \sum_{i=1}^{n} f_i\frac{\partial\left(\log x_i\right)}{\partial\left(\log q_r\right)} - \gamma g_r = 0.$$

The matrix form of equation (4.31) is

(4.25) $\underset{\sim}{\iota}'\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}=\gamma \underset{\sim}{g}'$ □

Similar to Lemma 4.2, equation (4.2) is differentiated with respect to $\log w_i$ to obtain term $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$.

Lemma 4.4: Solve the cost minimization problem described in equations (4.1) and (4.2), and then it is derived that

(4.33) $\underset{\sim}{\iota}'\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}=\underset{\sim}{0}$

Proof:

Differentiate equation (4.2) with respect to $\log w_i$

(4.34) $\sum_{j=1}^{n}\frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)}\frac{\partial\left(\log x_j\right)}{\partial\left(\log w_i\right)}=0$

and multiply both sides by γ

(4.35) $\sum_{j=1}^{n}\gamma\frac{\partial\left(h\left(\underset{\sim}{x},\underset{\sim}{q}\right)\right)}{\partial\left(\log x_i\right)}\frac{\partial\left(\log x_j\right)}{\partial\left(\log w_i\right)}=0$.

Substitute equation (4.29) into equation (4.35):

(4.36) $\sum_{j=1}^{n}f_i\frac{\partial\left(\log x_j\right)}{\partial\left(\log w_i\right)}=0$.

The matrix form of equation (4.36) is

(4.33) $\underset{\sim}{\iota}'\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}=\underset{\sim}{0}$ □

Thus, terms $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}$ and $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$ are included in equations (4.25) and (4.33).

These two equations are combined into a system below in equation (4.38).

(4.38) $$\begin{bmatrix}\underset{\sim}{\boldsymbol{\iota}}' & \underset{\sim}{0}\end{bmatrix}\begin{bmatrix}\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)} & \mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)} \\ -\frac{\partial\left(\log \rho\right)}{\partial\left(\log \underset{\sim}{q}'\right)} & -\frac{\partial\left(\log \rho\right)}{\partial\left(\log \underset{\sim}{w}'\right)}\end{bmatrix}=\begin{bmatrix}\gamma \underset{\sim}{g}' & \underset{\sim}{0}\end{bmatrix}.$$

In Lemma 4.5, a new system of equations (4.43) is set up through combining common terms in equations (4.24) and (4.38). This system is solved to get term $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$.

Lemma 4.5: Solve the cost minimization problem described in equations (4.1) and (4.2), and then it is derived that

(4.39) $$\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}=-\psi\left(\mathbf{\Theta}-\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{\theta}}'\right),$$

where

(4.40) $$\mathbf{\Theta}=\frac{1}{\psi}\mathbf{F}\left(\mathbf{F}-\gamma\mathbf{H}\right)^{-1}\mathbf{F},$$

(4.41) $$\underset{\sim}{\boldsymbol{\theta}}=\mathbf{\Theta}\underset{\sim}{\iota},$$

and

(4.42) $$\psi=\underset{\sim}{\iota}'\mathbf{F}\left(\mathbf{F}-\gamma\mathbf{H}\right)^{-1}\mathbf{F}\underset{\sim}{\iota}.$$

Proof:

Combine equation systems (4.24) and (4.38) together to obtain:

(4.43) $$\begin{bmatrix} \mathbf{F}^{-1}(\mathbf{F}-\gamma\mathbf{H})\mathbf{F}^{-1} & \underset{\sim}{\boldsymbol{\iota}} \\ \underset{\sim}{\boldsymbol{\iota}}' & \underset{\sim}{0} \end{bmatrix} \begin{bmatrix} \mathbf{F}\dfrac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')} & \mathbf{F}\dfrac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')} \\ -\dfrac{\partial(\log \rho)}{\partial(\log \underset{\sim}{q}')} & -\dfrac{\partial(\log \rho)}{\partial(\log \underset{\sim}{w}')} \end{bmatrix} = \begin{bmatrix} \gamma\mathbf{F}^{-1}\mathbf{H}^{*} & -\mathbf{I} \\ \gamma \underset{\sim}{g}' & \underset{\sim}{0} \end{bmatrix}.$$

The inverse of matrix $\begin{bmatrix} \mathbf{F}^{-1}(\mathbf{F}-\gamma\mathbf{H})\mathbf{F}^{-1} & \underset{\sim}{\boldsymbol{\iota}} \\ \underset{\sim}{\boldsymbol{\iota}}' & \underset{\sim}{0} \end{bmatrix}$ is

(4.44) $$\begin{bmatrix} \mathbf{F}^{-1}(\mathbf{F}-\gamma\mathbf{H})\mathbf{F}^{-1} & \underset{\sim}{\boldsymbol{\iota}} \\ \underset{\sim}{\boldsymbol{\iota}}' & \underset{\sim}{0} \end{bmatrix}^{-1} = \begin{bmatrix} \psi(\boldsymbol{\Theta}-\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{\theta}}') & \underset{\sim}{\boldsymbol{\theta}} \\ \underset{\sim}{\boldsymbol{\theta}}' & -1/\psi \end{bmatrix}.$$

Premultiply both sides of equation (4.43) by $\begin{bmatrix} \mathbf{F}^{-1}(\mathbf{F}-\gamma\mathbf{H})\mathbf{F}^{-1} & \underset{\sim}{\boldsymbol{\iota}} \\ \underset{\sim}{\boldsymbol{\iota}}' & \underset{\sim}{0} \end{bmatrix}^{-1}$ and substitute

equation (4.44) into (4.43):

(4.45) $$\begin{bmatrix} \mathbf{F}\dfrac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')} & \mathbf{F}\dfrac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')} \\ -\dfrac{\partial(\log \rho)}{\partial(\log \underset{\sim}{q}')} & -\dfrac{\partial(\log \rho)}{\partial(\log \underset{\sim}{w}')} \end{bmatrix} = \begin{bmatrix} \psi(\boldsymbol{\Theta}-\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{\theta}}')\gamma\mathbf{F}^{-1}\mathbf{H}^{*} + \gamma\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{g}}' & -\psi(\boldsymbol{\Theta}-\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{\theta}}') \\ \gamma\underset{\sim}{\boldsymbol{\theta}}'\mathbf{F}^{-1}\mathbf{H}^{*} - \gamma \underset{\sim}{g}'/\psi & -\underset{\sim}{\boldsymbol{\theta}}' \end{bmatrix},$$

and solve for $\mathbf{F}\dfrac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')}$ and $\mathbf{F}\dfrac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')}$ as follows:

(4.46) $$\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{q}')} = \gamma\psi(\boldsymbol{\Theta}-\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{\theta}}')\mathbf{F}^{-1}\mathbf{H}^{*} + \gamma\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{g}}'$$

and

(4.39) $$\mathbf{F}\frac{\partial(\log \underset{\sim}{x})}{\partial(\log \underset{\sim}{w}')} = -\psi(\boldsymbol{\Theta}-\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{\theta}}').$$ □

Thus, terms $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}$ and $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$ have been obtained. Although $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}$ is also obtained in equation (4.46), additional derivation is required to obtain a more easily estimated representation (Laitinen 1980), which is achieved in equation (4.47) in Lemma 4.6.

Lemma 4.6: Solve the cost minimization problem described in equations (4.1) and (4.2), and then it is derived that

(4.47) $$\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)} = \gamma\mathbf{KG}$$

Proof:

Define

(4.48) $$\theta_i^r = \frac{\partial\left(w_i x_i\right)/\partial q_r}{\partial C/\partial q_r},$$

which is the share of the *i*th input in the marginal cost of the *r*th product. After algebraic operations and substitution, equation (4.49) is obtained:

(4.49) $$\theta_i^r = \frac{w_i x_i}{\partial C/\partial q_r}\frac{\partial\left(\log x_i\right)}{\partial\left(\log q_r\right)}\frac{1}{q_r} = \frac{w_i x_i}{\rho g_r}\frac{\partial\left(\log x_i\right)}{\partial\left(\log q_r\right)} = \frac{Cf_i}{\rho g_r}\frac{\partial\left(\log x_i\right)}{\partial\left(\log q_r\right)} = \frac{f_i}{\gamma g_r}\frac{\partial\left(\log x_i\right)}{\partial\left(\log q_r\right)},$$

where the first equality is achieved by taking natural logarithm, the second equality is reached by substituting $\partial C/\partial q_r$ from equation (4.26) into θ_i^r, the third equality is derived from the definition of f_i, and the last equality is achieved by using equation (4.14).

Define $\mathbf{K}$ as the $n \times m$ matrix having θ_i^r as its $\left(i,\cdot\right)$th element and write equation (4.49) in the form of matrix, (4.50) $\mathbf{K} = \gamma^{-1}\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}\mathbf{G}^{-1}$,

where $\mathbf{G}$ is the $m \times m$ matrix with g_r, which is defined in equation (4.26), on the diagonal, and g_r is the product share, i.e.

(4.51) $g_r = \frac{p_r q_r}{R}$,

where R is the total revenue and

(4.52) $R = \sum_{r=1}^{m} p_r q_r$.

Equation (4.47) is derived from equation (4.50)

(4.47) $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)} = \gamma\mathbf{KG}$ □

With $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$ and $\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}$ obtained in equations (4.39) and (4.47), the theoretical import demand system is derived in equation (4.53) in Lemma 4.7, from which estimation stems.

Lemma 4.7: Solve the cost minimization problem described in equations (4.1) and (4.2), and then it is derived that

(4.53) $\mathbf{F}d\left(\log \underset{\sim}{x}\right) = \gamma\mathbf{KG}d\left(\log \underset{\sim}{q}\right) - \psi\left(\mathbf{\Theta} - \underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{\theta}}'\right)d\left(\log \underset{\sim}{w}\right)$

Proof:

The optimal input quantity is a function of output quantities and input prices, i.e.

(4.54) $x_i = x_i\left(\underset{\sim}{q}, \underset{\sim}{w}\right)$.

The matrix form of the total derivative of equation (4.54) is

$$(4.55)\quad d\left(\log \underset{\sim}{x}\right)=\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}d\left(\log \underset{\sim}{q}\right)+\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}d\left(\log \underset{\sim}{w}\right).$$

Multiply both sides of equation (4.55) by $\mathbf{F}$

$$(4.56)\quad \mathbf{F}d\left(\log \underset{\sim}{x}\right)=\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)}d\left(\log \underset{\sim}{q}\right)+\mathbf{F}\frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}d\left(\log \underset{\sim}{w}\right).$$

Substitute equations (4.38) and (4.47) into equation (4.56):

$$(4.53)\quad \mathbf{F}d\left(\log \underset{\sim}{x}\right)=\gamma\mathbf{KG}d\left(\log \underset{\sim}{q}\right)-\psi\left(\mathbf{\Theta}-\underset{\sim}{\boldsymbol{\theta}}\underset{\sim}{\boldsymbol{\theta}}'\right)d\left(\log \underset{\sim}{w}\right).$$ □

Equation (4.53) is the input demand equation. The *i*th input is

$$(4.57)\quad f_i d\left(\log x_i\right)=\gamma\sum_{r=1}^{m}\theta_i^r g_r d\left(\log q_r\right)-\psi\sum_{j=1}^{n}\left(\theta_{ij}-\theta_i\theta_j\right)d\left(\log w_j\right).$$

Equation (4.57) implies that the change in the demand for the *i*th input weighted by its cost factor share is a function of output quantity changes and input price changes.

4.5.2 Stage Two: Profit Maximization

In this stage, an output supply system is derived from solving a profit maximization problem in producer theory. Details of deriving this input demand system are discussed in Laitinen (1980). The profit maximization problem for a firm with *n* inputs and *m* outputs is to choose output q_r to maximize the profit function

$$(4.58)\quad \underset{\underset{\sim}{q}}{Max}\left(\pi\sum_{r=1}^{m}p_r q_r-C\left(\underset{\sim}{q},\underset{\sim}{w}\right)\right),$$

where $\underset{\sim}{p}=\left[p_r\right]'=\left[p_1,...,p_m\right]'$ is the output price vector. The first order condition of solving this profit maximization problem is

(4.59) $$\frac{\partial\left(\sum_{r=1}^{m} p_r q_r\right)}{\partial \underset{\sim}{q}} = \frac{\partial C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q}}$$

and

(4.60) $$\frac{\partial C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q}} = p_r .$$

The theoretical output supply system is shown in equation (4.85), which is derived by substituting two terms, $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)}$ and $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$, into equation (4.88). Equation (4.88) is derived from a total derivative of equation (4.60). Laitinen (1980) shows how to derive terms $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)}$ and $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$ from a profit maximization problem. Lemma 4.8 and Lemma 4.9 differentiate equation (4.60) with respect to p_s and w_i and then solves for $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)}$ and $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$, respectively. Equation (4.85) is obtained through substituting equation (4.61) for $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)}$ and equation (4.71) for $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$ into equation (4.56), which is derived from a total differentiation of the optimal input quantity, $q_i\left(\underset{\sim}{w}, \underset{\sim}{p}\right)$.

First, in order to obtain term $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)}$, equation (4.60) is differentiated with respect to p_s. Equation (4.61) in Lemma 4.8 is obtained after performing algebraic operations.

Lemma 4.8: Solve the profit maximization problem described in equation (4.58), and then it is derived that

$$(4.61)\quad \mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)} = \psi * \mathbf{\Theta} *,$$

where

$$(4.62)\quad \psi * \mathbf{\Theta} * = \frac{1}{R}\mathbf{P}\left(\frac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q}\partial \underset{\sim}{q}'}\right)^{-1}\mathbf{P}.$$

Proof:

Differentiate equation (4.60) with respect to p_s:

$$(4.63)\quad \sum_{t=1}^{m}\frac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial q_r \partial q_t}\frac{\partial q_t}{\partial p_s} = \delta_{rs},$$

where $\delta_{rs} = \begin{cases} 1 & r = s \\ 0 & r \neq s \end{cases}$. Multiply both sides of equation (4.63) by p_s,

$$(4.64)\quad \sum_{t=1}^{m}\frac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial q_r \partial q_t} q_t \frac{\partial\left(\log q_t\right)}{\partial\left(\log p_s\right)} = \delta_{rs} p_s.$$

In cost minimization problem, it is derived that

$$(4.26)\quad g_r = \frac{q_r}{\rho}\frac{\partial C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial q_r},$$

where ρ is the Lagrangean multiplier in the cost minimization problem, and

(4.65) $\rho = R$,

where R is the total revenue. Equations (4.26), (4.60) and (4.65) indicate that

(4.66) $q_t = \dfrac{Rg_t}{p_t}$.

Put equation (4.66) into equation (4.64),

(4.67) $\sum_{t=1}^{m} \dfrac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial q_r \partial q_t} \dfrac{Rg_t}{p_t} \dfrac{\partial\left(\log q_t\right)}{\partial\left(\log p_s\right)} = \delta_{rs} p_s$.

The matrix form of equation (4.67) is

(4.68) $R \dfrac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q} \partial \underset{\sim}{q}'} \mathbf{P}^{-1} \mathbf{G} \dfrac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)} = \mathbf{P}$,

where $\mathbf{P}$ is the $m \times m$ diagonal matrix of output prices and $\mathbf{G}$ is defined in equation (4.50). Multiply both sides of equation (4.62) by $\dfrac{1}{R} \mathbf{P} \left(\dfrac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q} \partial \underset{\sim}{q}'} \right)^{-1}$,

(4.69) $\mathbf{G} \dfrac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)} = \dfrac{1}{R} \mathbf{P} \left(\dfrac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q} \partial \underset{\sim}{q}'} \right)^{-1} \mathbf{P}$.

Define

(4.70) $\psi * \mathbf{\Theta} * = \dfrac{1}{R} \mathbf{P} \left(\dfrac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q} \partial \underset{\sim}{q}'} \right)^{-1} \mathbf{P}$,

and rewrite equation (4.69) as

(4.61) $\mathbf{G} \dfrac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)} = \psi * \mathbf{\Theta} *$. □

In order to obtain term $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$, equation (4.60) is differentiated with respect to w_i. Equation (4.71) in Lemma 4.9 is obtained after performing algebraic operations.

Lemma 4.9: Solve the profit maximization problem described in equation (4.58), and then it is derived that

$$(4.71)\quad \mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)} = -\psi^{*}\boldsymbol{\Theta}^{*}\mathbf{K}'$$

Proof:

Differentiate equation (4.60) with respect to w_i,

$$(4.72)\quad \frac{\partial^2 C\left(\underset{\sim}{q},\underset{\sim}{w}\right)}{\partial q_r \partial w_i} + \sum_{s=1}^{m}\frac{\partial^2 C\left(\underset{\sim}{q},\underset{\sim}{w}\right)}{\partial q_r \partial q_s}\frac{\partial q_s}{\partial w_i} = 0\,.$$

Solve $\frac{\partial \underset{\sim}{q}}{\partial \underset{\sim}{w}}$ in the matrix form

$$(4.73)\quad \frac{\partial \underset{\sim}{q}}{\partial \underset{\sim}{w}} = -\left(\frac{\partial^2 C\left(\underset{\sim}{q},\underset{\sim}{w}\right)}{\partial \underset{\sim}{q}\partial \underset{\sim}{q}'}\right)^{-1}\frac{\partial^2 C\left(\underset{\sim}{q},\underset{\sim}{w}\right)}{\partial \underset{\sim}{q}\partial \underset{\sim}{w}'},$$

where

$$(4.74)\quad \frac{\partial^2 C\left(\underset{\sim}{q},\underset{\sim}{w}\right)}{\partial \underset{\sim}{q}\partial \underset{\sim}{w}'} = \left(\frac{\partial^2 C\left(\underset{\sim}{q},\underset{\sim}{w}\right)}{\partial \underset{\sim}{w}\partial \underset{\sim}{q}'}\right)' = \left(\frac{\partial \underset{\sim}{x}}{\partial \underset{\sim}{q}'}\right)'.$$

Equation (4.50) implies that

$$(4.75)\quad \frac{\partial\left(\log \underset{\sim}{x}\right)}{\partial\left(\log \underset{\sim}{q}'\right)} = \mathbf{X}^{-1}\frac{\partial \underset{\sim}{x}}{\partial \underset{\sim}{q}'}\mathbf{Q} = \gamma\mathbf{F}^{-1}\mathbf{K}\mathbf{G}$$

and

(4.76) $\frac{\partial \underset{\sim}{x}}{\partial \underset{\sim}{q}'} = \gamma \mathbf{X}\mathbf{F}^{-1}\mathbf{K}\mathbf{G}\mathbf{Q}^{-1}$,

where $\mathbf{X}$ is the $n \times n$ diagonal matrix with input quantities on diagonal and $\mathbf{Q}$ is the $m \times m$ matrix with output quantities on diagonal. The definitions of $\mathbf{F}$ and $\mathbf{G}$ imply that

(4.77) $\mathbf{F} = C^{-1}\mathbf{W}\mathbf{X}$

and

(4.78) $\mathbf{G} = R^{-1}\mathbf{P}\mathbf{Q}$,

where $\mathbf{W}$ is the $n \times n$ diagonal matrix with input prices on diagonal, $\mathbf{P}$ is the $m \times m$ matrix with output prices on diagonal, and C and R are total cost and revenue, respectively. Substitute equations (4.77) and (4.78) into equation (4.76), it is derived that

(4.79) $\frac{\partial \underset{\sim}{x}}{\partial \underset{\sim}{q}'} = \frac{C\gamma}{R}\mathbf{W}^{-1}\mathbf{K}\mathbf{P}$.

In order to solve equation (4.79), substitution from previous equations are required for R and γ:

(4.65) $\rho = R$,

and

(4.14) $\gamma = \frac{\rho}{C}$,

Substitute equations (4.65) and (4.14) into equation (4.79),

(4.80) $\frac{\partial \underset{\sim}{x}}{\partial \underset{\sim}{q}'} = \mathbf{W}^{-1}\mathbf{K}\mathbf{P}$.

Substitute equation (4.80) into equations (4.74):

(4.81) $\frac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q} \partial \underset{\sim}{w}'} = \mathbf{P}\mathbf{K}'\mathbf{W}^{-1}$.

Put equation (4.81) into equation (4.73):

$$(4.82)\quad \frac{\partial \underset{\sim}{q}}{\partial \underset{\sim}{w}'} = -\left(\frac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q} \partial \underset{\sim}{q}'}\right)^{-1} \mathbf{PK}'\mathbf{W}^{-1}.$$

Premultiply both sides of equation (4.82) by $\frac{1}{R}\mathbf{P}$ and then postmultiply both sides of equation (4.82) by $\mathbf{W}$:

$$(4.83)\quad \frac{1}{R}\mathbf{P}\frac{\partial \underset{\sim}{q}}{\partial \underset{\sim}{w}'}\mathbf{W} = -\frac{1}{R}\mathbf{P}\left(\frac{\partial^2 C\left(\underset{\sim}{q}, \underset{\sim}{w}\right)}{\partial \underset{\sim}{q} \partial \underset{\sim}{q}'}\right)^{-1} \mathbf{PK}'.$$

Put equations (4.70) and (4.78) into equation (4.83):

$$(4.84)\quad \mathbf{GQ}^{-1}\frac{\partial \underset{\sim}{q}}{\partial \underset{\sim}{w}'}\mathbf{W} = -\psi^{*}\mathbf{\Theta}^{*}\mathbf{K}'.$$

Rewrite equation (4.84) into a logarithmic form:

$$(4.71)\quad \mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)} = -\psi^{*}\mathbf{\Theta}^{*}\mathbf{K}'. \qquad \square$$

With $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)}$ and $\mathbf{G}\frac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)}$ obtained in equations (4.61) and (4.71), the theoretical output supply system is obtained in equation (4.85) in Lemma 4.10, from which estimation stems.

Lemma 4.10: Solve the profit maximization problem described in equation (4.58), and then it is derived that

$$(4.85)\quad \mathbf{G}d\left(\log \underset{\sim}{q}\right) = \psi^{*}\mathbf{\Theta}^{*}\left[d\left(\log \underset{\sim}{p}\right) - \mathbf{K}'d\left(d \log \underset{\sim}{w}\right)\right].$$

Proof:

The optimal output quantity is a function of output quantities and input prices, i.e.

(4.86) $q_i = q_i\left(\underset{\sim}{w}, \underset{\sim}{p}\right)$.

The matrix form of the total derivative of equation (4.86) is

(4.87) $d\left(\log \underset{\sim}{q}\right) = \dfrac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)} d\left(\log \underset{\sim}{w}\right) + \dfrac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)} d\left(\log \underset{\sim}{p}\right)$.

Multiply both sides of equation (4.87) by $\mathbf{G}$

(4.88) $\mathbf{G}d\left(\log \underset{\sim}{q}\right) = \mathbf{G}\dfrac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{w}'\right)} d\left(\log \underset{\sim}{w}\right) + \mathbf{G}\dfrac{\partial\left(\log \underset{\sim}{q}\right)}{\partial\left(\log \underset{\sim}{p}'\right)} d\left(\log \underset{\sim}{p}\right)$

Put equations (4.61) and (4.71) into equation (4.88):

(4.85) $\mathbf{G}d\left(\log \underset{\sim}{q}\right) = \psi^* \mathbf{\Theta}^* \left[d\left(\log \underset{\sim}{p}\right) - \mathbf{K}' d\left(d \log \underset{\sim}{w}\right)\right]$.

The derived output supply equation for the rth output is

(4.89) $g_r d\left(\log q_r\right) = \psi^* \sum_{s=1}^{m} \theta_{rs}^* \left[d\left(\log p_s\right) - \sum_{i=1}^{n} \theta_i^s d \log\left(w_i\right)\right]$. □

Equation (4.89) implies that the change in the supply for the rth output weighted by its factor share in revenue is a function of output price changes and input price changes. For agricultural imports, in many cases, output quantities are not available for estimation. This data availability problem can be overcome by introducing Divisia volume indices of input and output into estimation. Sum up both sides of equation (4.89) over output r and then equation (4.90) is obtained:

(4.90) $d\left(\log X\right) = \gamma \left[\sum_{r=1}^{m} \psi^* \sum_{s=1}^{m} \theta_{rs}^* \left[d\left(\log p_s\right) - \sum_{i=1}^{n} \theta_i^s d \log\left(w_i\right)\right]\right]$

where

(4.91) $d\left(\log X\right) = \sum_{i=1}^{n} f_i d\left(\log x_i\right)$ is the Divisia volume index of input, (4.92) $d\left(\log Q\right)=\sum_{r=1}^{m} g_r d\left(\log q_r\right)$ is the Divisia volume index of output,

and

(4.93) $d\left(\log X\right)=\gamma d\left(\log Q\right)$, i.e $d\left(\log X\right)$ and $d\left(\log Q\right)$ are proportional to each other, (Laitinen 1980).

Simplify equation (4.90), and equation (4.94) is derived

(4.94) $d\left(\log X\right)=\sum_{s=1}^{m}\varphi_s^* d\left(\log p_s\right)+\sum_{i=1}^{n}\pi_i^* d\left(\log w_i\right)$,

where $\varphi_r^* = \gamma\psi^*\varphi_{rs}$ and $\pi_i^* = -\gamma\psi^*\pi_{irs}$. Equation (4.94) is the total import expenditure equation.

4.5.3 The Model to be Estimated

In estimating China's soybean imports, $\underset{\sim}{x}=\left[x_i\right]'=\left[x_1,x_2,x_3\right]'$ is the vector of import quantities from three countries, where I = {i} = {1,2,3} = {the United States, Argentina, Brazil}. The price vector of these imports is $\underset{\sim}{w}=\left[w_i\right]'=\left[w_1,w_2,w_3\right]'$. The output quantity vector is $\underset{\sim}{q}=\left[q_r\right]'=\left[q_1,q_2\right]'$ containing two output quantities, where R = {r} = {1,2} = {Soybean Meal, Soybean Oil}. Then the corresponding output price vector is $\underset{\sim}{p}=\left[p_r\right]'=\left[p_1,p_2\right]'$. Equation (4.95) is the input demand equation for soybean imports from each country and based on the theoretical equation (4.57):

(4.95) $f_i d\left(\log x_i\right)=\gamma\sum_{r=1}^{2}\theta_i^r g_r d\left(\log q_r\right)-\psi\sum_{j=1}^{3}\left(\theta_{ij}-\theta_i\theta_j\right)d\left(\log w_j\right)$.

Equation (4.96) is the total expenditure equation for China's soybean crushing industry and based on the theoretical equation (4.94):

$$(4.96)\ d\left(\log X\right)=\sum_{s=1}^{2}\varphi_s^{*}d\left(\log p_s\right)+\sum_{i=1}^{3}\pi_i^{*}d\left(\log w_i\right)$$

However, the monthly soybean meal and oil outputs in China, q_r, are not available. Fixed crushing ratios of soybean meal and oil can help us overcome this problem. Soybeans are crushed to produce two products, soybean meal and oil. The crushing ratios for producing these two products are 79 and 18 percent, respectively. Historical data show that every year China's domestic soybean meal and oil markets clear. For soybean oil, from 2003 to 2007, the percentage of annual stocks was not higher than two percent. For soybean meal, there was no annual stock, and the percentage of annual net exports was not higher than four percent. The percentages of net stock in China's soybean oil supply and net export in China's soybean meal supply are contained in Table 4.1. Annual soybean consumption from 2002 to 2007 derived from China's production of soybean meal and oil are displayed in Table 4.2. These results are compared to China's consumption of crush consumption soybeans. The differences among these three data series are very small. Therefore, Tables 4.1 and 4.2 imply that China's domestic soybean meal and oil markets clear every year, and China's domestic soybean meal and oil are produced in proportion based on their crushing ratios, 79 and 18 percent, respectively.

Table 4.1. Percentages of Net Export in China's Soybean Meal Supply and Net Stock in China's Soybean Oil Supply

	2002	2003	2004	2005	2006	2007
Percentages of Net Export of China's Soybean Meal Supply	4.1%	3.1%	2.3%	-1.8%	3.0%	0.3%
Percentages of Net Stock of China's Soybean Oil Supply	0.6%	2.0%	-1.3%	-0.6%	0.6%	-0.7%

Source: USDA, FAS (2004d, 2005d, 2006c, 2007a, 2008a, and 2008e)

Table 4.2. Comparison of China's Consumption of Soybeans (Unit: MMT)

	2002	2003	2004	2005	2006	2007
China's Consumption of Soybeans Calculated from Soybean Meal Production	26.6	25.3	31.4	35.1	35.6	38.6
China's Consumption of Soybeans Calculated from Soybean Oil Production	25.8	25.0	31.1	34.2	35.2	38.2
China's Consumption of Soybeans in USDA Report	26.5	25.3	31.3	34.5	35.5	38.5

Source: USDA, FAS (2004d, 2005d, 2006c, 2007a, 2008a, and 2008e)

Using the crushing ratios of the soybean industry and the presumption of market clear for the Chinese domestic soybean meal and oil markets, it is derived that

(4.97) $\frac{q_1}{q_2} = \frac{0.79}{0.18} = 4.39$

and

(4.98) $q_1 = 4.39 q_2$.

In order to obtain the input demand equation (4.95) for this problem, substitute equation (4.98) into $\theta_i^2 = \frac{\partial(w_i x_i)}{\partial q_2} \Big/ \frac{\partial C}{\partial q_2}$ and get

(4.99) $\theta_i^2 = \frac{\partial(w_i x_i)}{\partial q_2} \Big/ \frac{\partial C}{\partial q_2} = \frac{\partial(w_i x_i)}{\partial(4.39 q_1)} \Big/ \frac{\partial C}{\partial(4.39 q_1)} = \frac{\partial(w_i x_i)}{\partial q_1} \Big/ \frac{\partial C}{\partial q_1} = \theta_i^1$.

Now define $\theta_i^1 = \theta_i^2 = \theta_i^c$, and equation (4.95) is re-written as equation (4.100)

(4.100) $f_i d(\log x_i) = \gamma \theta_i^c \sum_{r=1}^{2} g_r d(\log q_r) - \psi \sum_{j=1}^{3} (\theta_{ij} - \theta_i \theta_j) d(\log w_j)$.

Substitute Divisia volume index of input into equation (4.100), and then equation (4.101) is derived as

(4.101) $f_i d(\log x_i) = \theta_i^c d(\log X) + \sum_{j=1}^{3} \pi_{ij} d(\log w_j)$, where $\theta_i^c = \theta_i^r$ for any r and $\pi_{ij} = -\psi\left(\theta_{ij} - \theta_i\theta_j\right)$. Equation (4.101) indicates that the change in the share of each soybean imports from a source country is a function of Divisia volume index of input quantities and the changes of the prices of China's soybean imports from all three countries.

In empirical research, the finite versions of Equation (4.101) and (4.96) will be estimated. The finite version of Equation (4.101) is

(4.102) $$\overline{f}_{it}\Delta x_{it} = \theta_i^c \Delta X_t + \sum_{j=1}^{3} \pi_{ij}\Delta w_{jt} + \varepsilon_{it},$$

where $\overline{f}_{it} = \left(f_{it} + f_{it-1}\right)/2$, $\Delta x_{it} = \log\left(x_{it}/x_{it-1}\right)$, $\Delta X_t = \sum_{i=1}^{n} \overline{f}_{it}\Delta x_{it}$, and $\Delta w_{jt} = \log\left(w_{jt}/w_{jt-1}\right)$. The finite version of Equation (4.96) is

(4.103) $$\Delta X_t = \sum_{s=1}^{2} \varphi_s^* \Delta p_{st} + \sum_{i=1}^{3} \pi_i^* \Delta w_{it} + \nu_t,$$

where $\Delta p_{st} = \log\left(p_{st}/p_{st-1}\right)$. Normally, the total expenditure is also influenced by prices of other resources like labor, fuel and electricity (Muhammad 2009). Because China's monthly prices of these resources are not available, in estimation, a constant proxy is put in Equation (4.104) to represent these price effects and the final finite version of the total expenditure equation to be estimated is

(4.104) $$\Delta X_t = \alpha_0 + \sum_{s=1}^{2} \varphi_s^* \Delta p_{st} + \sum_{i=1}^{3} \pi_i^* \Delta w_{it} + \nu_t.$$

The final system to be estimated consists of equations (4.102) and (4.104):

(4.105) $$\begin{cases} \overline{f}_{it}\Delta x_{it} = \theta_i^c \Delta X_t + \sum_{j=1}^{3} \pi_{ij}\Delta w_{jt} + \varepsilon_{it} \\ \Delta X_t = \alpha_0 + \sum_{s=1}^{2} \varphi_s^* \Delta p_{st} + \sum_{i=1}^{3} \pi_i^* \Delta w_{it} + \nu_t \end{cases}$$

According to the producer theory, price coefficient, π_{ij}, is expected to be negative for $i = j$. This means that when the price of China's soybean imports from country i increases, China's soybean imports from this country are expected to decrease. For $i \neq j$, when the price of China's soybean imports from country j increases, China's soybean imports from country i are expected to increase, i.e. $\pi_{ij} > 0$, if imports from countries i and j are substitutes. If imports from countries imports from countries i and j are complements, then $\pi_{ij} < 0$, and when the price of China's soybean imports from country j increases, China's soybean imports from country i are expected to decrease. Marginal factor share, θ_i^c, measures when China's total soybean imports increase, how its soybean imports from a specific source country change.

In the total expenditure equation, import price coefficient, π_i^*, measures when the price of China's soybean imports from a specific country increases, how the total import expenditure changes. Output price coefficient, φ_s^*, is expected to be positive. This represents that when China's domestic soybean oil or meal price increases, China's total soybean imports should increase.

In estimating the demand equation system, a series of restrictions will be tested and/or imposed on the import demand system (Laitinen 1980),

(4.106) Adding up: $\sum_{i=1}^{3} \theta_i^c = 1$ and $\sum_{i=1}^{3} \pi_{ij} = 0$;

(4.107) Homogeneity: $\sum_{j=1}^{3} \pi_{ij} = 0$;

(4.108) Symmetry: $\pi_{ij} = \pi_{ji}$;

(4.109) Negative Semidefinite: $\Pi = \left[\pi_{ij}\right]$

4.5.4 Elasticities

Estimates of the differential production model can be applied to calculate elasticities of the model. Conditional own-price/cross-price elasticity is:

(4.110) $\eta_{ij}^{c} = \dfrac{d\log\left(x_i\right)}{d\log\left(w_j\right)} = \dfrac{\pi_{ij}}{\bar{\bar{f}}_i}$.

Equation (4.110) measures when the price of China's soybean imports from country j increases one percent, how imports from country i will change, holding China's total soybean imports constant. For $i = j$, equation (4.110) is conditional own-price elasticity. For $i \neq j$, equation (4.110) is conditional cross-price elasticity.

Conditional Divisia index elasticity is

(4.111) $\eta_{i} = \dfrac{d\log\left(x_i\right)}{d\left(\log X\right)} = \dfrac{\theta_i^{c}}{\bar{\bar{f}}_i}$.

Equation (4.111) measures when China's total soybean imports increase one percent how imports from a specific country will change.

Unconditional own-price/cross-price elasticity is

(4.112) $\eta_{ij} = \dfrac{d\log\left(x_i\right)}{d\log\left(w_j\right)} = \dfrac{\pi_{ij}}{\bar{\bar{f}}_i} + \dfrac{\theta_i^{c}}{\bar{\bar{f}}_i}\pi_j^{*}$.

Equation (4.112) measures when the price of China's soybean imports from country j increases one percent, how imports from country i will change, considering effects through China's total soybean imports. For $i = j$, equation (4.112) is unconditional own-price elasticity. For $i \neq j$, equation (4.112) is unconditional cross-price elasticity.

Unconditional output price elasticity is

$$(4.113)\quad \eta_{ir} = \frac{d\log(x_i)}{d\log(p_s)} = \frac{\theta_i^c}{\overline{f}_i}\varphi_s^*.$$

Equation (4.113) measures when the price of China's domestic soybean meal or oil increases one percent how China's soybean imports from a specific country change.

4.6. Estimation

4.6.1 General Introduction

The system is estimated for two models. These two models are the same in the import demand system, the top part of equation (4.105), but different in the total import expenditure equation, the lower part of equation (4.105).

In the first model, the output is China's domestic soybeans. Imported soybeans are sold on China's domestic markets after transportation, unloading, and packaging. These activities result in a significant amount of domestic value added (Muhammad 2007). Therefore, domestic soybeans are considered as an output in this type. In the second model, the outputs are soybean meal and oil, which are crushed from imported soybeans. Section 4.1 introduces China's soybean marketing system. China imports soybeans from global markets to meet its domestic demand for soybean meal and oil. Soybean imports have dominated China's soybean meal and oil production. Thus, it is also feasible to treat soybean meal and oil as outputs. For each model, estimation includes conditional and unconditional price elasticities.

Because the import demand system is singular, one equation is deleted in estimation to avoid the singularity problem. The estimates in the deleted equation are obtained by using the property of adding-up. The import demand system must be statistically sound before imposing the theoretical restrictions – homogeneity and symmetry. With the estimation of the total expenditure equation, a series of elasticities are calculated.

Because ΔX_t appears as an explanatory variable in Equation (4.36) and a dependent variable in Equation (4.37), before estimating the system, it is required to test if endogeneity exists in the system. If endogeneity does not exist, then the derived demand for individual imports and the total import expenditure equation can be estimated separately, otherwise, instrumental variables (IV) are required. The endogeneity is tested by applying Durbin-Wu-Hausman test, which is based upon auxiliary regressions (Verbeek 2004). The test results Table 4.3 indicate that endogeneity does not exist in the models. Then the import demand system and the total import expenditure equation can be estimated separately. The import demand system is estimated by using ITSUR (iterative seemingly unrelated regression) method and the total import expenditure equation is estimated by using OLS (ordinary least square) method.

Table 4.3. Durbin-Wu-Hausman Test for the Endogeneity of Divisia Volume Index of Input, H_0 : Endogeneity does not exist

Outputs: Soybeans			Outputs: Soybean Meal and Oil		
Statistic	DF	Pr > ChiSquare	Statistic	DF	Pr > ChiSquare
0.02	2	0.9909	1.26	2	0.5337

Wald tests are conducted to test if endogeneity exists

4.6.2 Model One: Three Source Countries, One Output

The test results in Table 4.4 indicate that the null hypotheses that there is neither heteroskedasticity nor first-order autocorrelation in residuals cannot be rejected. Therefore, the model is statistically sound. The theoretical restrictions of homogeneity and symmetry cannot be rejected either. Therefore, the system is estimated with these restrictions imposed. The estimation results displays in Table 4.5. Table 4.6 presents total import expenditure estimates. Elasticities are contained in Table 4.7 and 4.8.

Table 4.4. Tests on Statistical Adequacy (No Autocorrelation and No Heteroskedasticity in Residuals) and Theoretical Restrictions (Homogeneity and Symmetry), Three Exporters, One Output

	H_0 : No Heteroskedasticity in Residuals			H_0 : No AR(1) in Residuals		
	Statistic	DF	Pr > ChiSq	LM	DF	Pr > LM
Equation for Total Import Expenditure	16.42	14	0.2884	0.68	1	0.4107
Equation for United States	12.54	14	0.5702	0.77	1	0.3797
Equation for Brazil	9.17	14	0.8199	0.55	1	0.4585
	Statistic	DF	Pr > ChiSq			
Homogeneity	0.04	2	0.9796			
Symmetry	2.53	1	0.1116			

In Table 4.5, the price coefficient of China's soybean imports from the U.S. is negative and significant as expected. This implies that China's soybean imports from the U.S. decreased when its own price increased. The own price coefficients of China's soybean imports from Argentina and Brazil are both insignificant. This indicates that the own prices of these two countries had no impacts on China's soybean imports from these two countries. The sign of the own price coefficient of Argentina is positive and not consistent with theory, but the sign of Brazil is negative and consistent with theory. In the equation of China's soybean imports from the U.S., the price coefficient of imports from Brazil is positive and significant. This implies that China's soybean imports from the U.S. increased when the price of soybean imports from Brazil increased. By symmetry, China's soybean imports from Brazil increased when the price of soybean imports from the U.S. increased. Therefore, price coefficients in Table 4.5 indicate that China's soybean imports from the U.S. and Brazil were substitutes. However no such relationship existed between China's soybean imports from the U.S. and Argentina or Brazil and Argentina.

Marginal factor shares in Table 4.5 indicate that there were positive and significant relationships between total import expenditures and source-specific imports. When total import expenditure increased, imports from Argentina increased more than that from the United States and Brazil. This is consistent with the observation across the period from 2003 to 2007, when China's total soybean imports and its imports from all three suppliers increased. The three eigenvalues of the estimate matrix $\left[\pi_{ij}\right]$ are all non-positive and indicate negative semidefiniteness holds for this estimation.

Table 4.5. Conditional Import Demand Estimates of China's Soybean Imports, Three Exporters, One Output

Imports From	Price Coefficient, π_{ij}			Marginal Factor Share, θ_i^c
	The United States	Argentina	Brazil	
The United States	-0.8991 (0.2479) ***	0.0041 (0.2703)	0.8950 (0.1683) ***	0.3093 (0.0533) ***
Argentina		0.3530 (0.4192)	-0.3571 (0.3897)	0.4238 (0.0637) ***
Brazil			-0.5379 (0.4636)	0.2670 (0.0587) ***

Significance levels: ***0.01; **0.05; *0.10.

Estimation results in Table 4.6 imply that the impact of soybean import price from Brazil on total expenditures was significantly negative and consistent with theory, but that from Argentina was significantly positive and not consistent with theory. Output (soybeans on China's domestic markets) price coefficient was significant but negative, which means that an increase in the China's domestic soybean price led to decrease in

China's total soybean imports. This is not consistent with theoretical implications. Soybean meal and oil will be treated as outputs and estimated in 4.6.3.

Table 4.6. Total Import Expenditure Estimates, Three Exporters, One Output

Import Price Coefficient, π_i^*				Output Price Coefficient, φ_s^*
Constant	The U.S.	Argentina	Brazil	Soybeans
0.4014 (0.2726)	0.0291 (0.0572)	2.6534 (0.4220) ***	-0.5283 (0.2013) **	-2.4810 (0.4729) ***

Significance levels: ***0.01; **0.05; *0.10

Table 4.7. Conditional Price and Divisia Index Elasticities of the Derived Demand for China's Soybean Imports, Three Exporters, One Output

Imports from	Conditional Price Elasticity, η_{xw}^c			Conditional Divisia Index Elasticity, η_{xX}
	The United States	Argentina	Brazil	
The United States	-2.2506 (0.6205) ***	0.0103 (0.6766)	2.2404 (0.4213) ***	0.7741 (0.1333) ***
Argentina	0.0166 (1.0925)	1.4268 (1.6943)	-1.4434 (1.5752)	1.7128 (0.2576) ***
Brazil	2.5348 (0.4766) ***	-1.0113 (1.1037)	-1.5235 (1.3129)	0.7561 (0.1661) ***

Significance levels: ***0.01; **0.05; *0.10

Conditional Price and Divisia index elasticities are displayed in Table 4.7. As expected, China's soybean imports from the U.S. was price elastic to its own price. Soybean imports from Brazil and the United States were substitutes to each other on China's soybean import markets. Holding total import expenditure constant, when the price of China's soybean imports from the U.S. increased one percent, its soybean imports from the U.S. decreased 2.25 percent, but its soybean imports from Brazil increased 2.53 percent; when the price of China's soybean imports from Brazil increased one percent, its soybean imports from the U.S. increased 2.24 percent. Thus, conditional price elasticity indicates that China's soybean imports from the U.S. and Brazil were substitutes. China's soybean imports from Argentina were not affected by either its own price or prices of imports from the U.S. or Brazil. Moreover, the price of imports from Argentina did not affect China's soybean imports from the other two countries. Argentina's conditional own price elasticity is insignificantly positive. This is not consistent with theory.

The Divisia index elasticities measure how China's soybean imports from a specific source change when China's total soybean imports change. The Divisia index elasticities of all three countries were significant and positive, which means that when China's total soybean imports increased, China's soybean imports from each specific country increased also. When China's total soybean imports increased one percent, China's soybean imports from the U.S., Argentina and Brazil increased 0.77, 1.71 and 0.76 percent, respectively.

Table 4.8. Unconditional Price and Output Price Elasticities of the Derived Demand for China's Soybean Imports, Three Exporters, One Output

Imports from	Unconditional Price Elasticities, η_{xw}			Unconditional Output Price Elasticities, η_{xp}
	The United States	Argentina	Brazil	Soybeans on China's Market
The United States	-2.2807 (0.6228) ***	2.0643 (0.8353) ***	1.8315 (0.4547) ***	-1.9207 (0.5038) ***
Argentina	0.0665 (1.0550)	5.9717 (1.8835) ***	-2.3483 (1.5868)	-4.250 (1.0523) ***
Brazil	2.5568 (0.4788) ***	0.9951 (1.2473)	-1.9229 (1.3195)	-1.8760 (0.5583) **

Significance levels: ***0.01; **0.05; *0.10

Unconditional price elasticities in Table 4.8 indicate that China's soybean imports from the U.S. were significantly unconditional price elastic to its own price and the prices of soybean imports from Argentina and Brazil. Considering the effects of changes in the total import expenditure, when the price of China's soybean imports from the U.S. increased one percent, China's soybean imports from this country decreased 2.28 percent, which is close to its corresponding conditional price elasticity. This is because that the import price coefficient of the U.S. in the total expenditure equation is small, 0.03 (Table 4.6), and the conditional Divisia index elasticity of the U.S. is 0.77 (Table 4.7). China's soybean imports from U.S. increased 2.06 and 1.83 percent, when the import prices from Argentina and Brazil increased one percent, respectively. China's soybean imports from Argentina increased 5.97 percent when its own price increased one percent. China's soybean imports from Brazil were not own-price elastic, but they were price elastic to the price of imports from the United States. When this price increased one percent, China's soybean imports from Brazil increased 2.56 percent. Thus, based on unconditional price elasticities, China's soybean imports from the U.S. and Brazil were substitutes to each other.

Because of a negative output price coefficient for soybeans, -2.48 (Table 4.6), and positive conditional Divisia index elasticities for all three countries, unconditional output price elasticities for soybeans are negative too. When China's domestic soybean price increased one percent, its soybean imports from the U.S., Argentina and Brazil decreased 1.92, 4.25 and 1.88 percent, respectively.

4.6.3. Model Two: Three Source Countries, Two Outputs

This model still contains three source countries of China's soybean imports – the U.S., Argentina, and Brazil, but has two outputs – soybean meal and oil. Therefore, the derived demand for an individual imports and the corresponding conditional price and Divisia index elasticities of the derived demand for China's soybean imports are the same as the previous section. However, the total import expenditure equation and the unconditional price and output price elasticities of the derived demand for China's soybean imports are different.

The total expenditure equation estimates in Table 4.9 indicate that the impact of soybean import price from the United States was negative and significant, however that from Brazil was also negative but insignificant. The impact of the price of soybeans imported from Argentina was significantly positive. The output price coefficient of soybean meal price was significantly negative and may not be consistent with theory. The output price coefficient of soybean oil was positive but insignificant.

Table 4.9. Total Expenditure Estimates, Three Exporters, Two Outputs

	Import Prices Coefficient, π_i^*			Output Price Coefficients, φ_s^*	
Constant	The U.S.	Argentina	Brazil	Soybean Meal	Soybean Oil
0.2703 (0.2455)	-2.5952 (0.7506) ***	3.4958 (0.5609) ***	-0.5723 (0.4951)	-0.9575 (0.4230) **	0.4345 (0.3339)

Significance levels: ***0.01; **0.05; *0.10

Although conditional price and Divisia index elasticities are the same as the previous part, but unconditional price and output price elasticities are different and contained in Table 4.10. There are two types of unconditional output price elasticities, one for soybean meal and another for soybean oil. Those for soybean meal were significantly negative, but those for soybean oil were positive but insignificantly. When China's domestic soybean meal price increased one percent, China's soybean imports from the U.S., Argentina and Brazil decreased 0.73, 1.69 and 0.70 percent, respectively. However, when China's domestic soybean oil price increased, changes in China's soybean imports from any of the source countries were insignificant. **This means that China's soybean imports from each of the source countries were significantly affected by its domestic soybean meal price but not by its domestic soybean oil price. This finding support the hypothesis based on China's marketing system of soybean products.**

The unconditional price elasticities indicate that China's soybean imports from the U.S. was price elastic to its own price and the prices of China's soybean imports from Argentina and Brazil. When its own price increased one percent, China's soybean imports from the U.S. decreased 4.33 percent. China's soybean imports from the U.S. increased 2.79 and 1.82 percent, when the prices of China's soybean imports from Argentina and Brazil increased one percent, respectively. China's soybean imports from Argentina were complements to imports from the United States. When the price of China's soybean imports from the U.S. increased one percent, China's soybean imports from Argentina decreased 4.44 percent. However, when the price of China's soybean imports from Argentina increased one percent, China's soybean imports from this country increased 7.42 percent. This is caused by a high import price coefficient of Argentina, 3.50 (Table 4.9).

Table 4.10. Unconditional Price and Output Price Elasticities of the Derived Demand for China's Soybean Imports, Three Exporters, Two Outputs

Imports from	Unconditional Price Elasticities, η_{xw}			Unconditional Output Price Elasticities, η_{xp}	
	The United States	Argentina	Brazil	China's Soybean Meal Price	China's Soybean Oil Price
The United States	-4.3283 (0.8544) ***	2.756 (1.0433) ***	1.8236 (0.5911) ***	-0.7323 (0.3554) **	0.3323 (0.2672)
Argentina	-4.4433 (1.2817) ***	7.4170 (1.9910) ***	-2.395 (1.5912)	-1.6885 (0.7600) **	0.7662 (0.5841)
Brazil	0.6606 (0.8777)	1.5853 (1.3419)	-2.0005 (1.3739)	-0.7003 (0.3454) **	0.3178 (0.2712)

Significance levels: ***0.01; **0.05; *0.10

4.6.4. Discussions

Two differential production models are estimated for China's soybean imports. They are different in outputs: the first model contains soybeans as an output and the second model contains soybean meal and oil as outputs. Conditional own price elasticity (Table 4.7) and unconditional price elasticities of both models (Tables 4.8 and 4.9) indicate that that when the price of China's soybean imports from Argentina increased, China's imports from Argentina increased. This is not consistent with the theory. Moreover, the absolute values of the price elasticities of imports from Argentina are very high (5.97 in Table 4.8 and 7.42 in Table 4.10). One possible answer to these unexpected estimates and elasticities may be related to China's large quantities of soybean oil imports from Argentina. From 2003 to 2007, Argentina's share in China's soybean oil imports increased from 66 percent to 81 percent and reached 1.95 MMT in 2007, which required to be crushed from an additional 10.83 MMT soybeans. Thus, in order to investigate the actual role of Argentina in China's soybean imports, soybean oil imports should be included in the model.

4.7. Conclusions

The estimation results and their corresponding elasticities imply the points about China's soybean import markets as following:

First, China's domestic prices of soybean meal and oil had different effects on its soybean imports. China's domestic price of soybean meal, but not soybean oil, significantly affected its soybean imports from the foreign markets. If the model contains only soybeans as outputs, the significant difference between China's domestic prices of soybean meal and oil will not be accounted for. This result supports the conclusion in Piggott and Wohlgenant (2002) that taking account of trade of soybean meal and oil has more profound impact on the responsiveness of total soybean demand than only taking account of soybeans.

Secondly, conditional and unconditional elasticities China's soybean imports from different source countries indicate that :

(1) Holding China's total soybean imports constant, China's soybean imports from the U.S. were price elastic to their own price and the price of China's soybean imports from Brazil. China's soybean imports from Argentina were not affected by either their own price or the prices of the other two countries. As to China's soybean imports from Brazil, they were price elastic to the price of soybean imports from the United States.

(2) Unconditional price elasticities indicate that, when two outputs – soybean meal and oil – are included in the model, China's soybean imports from the U.S. were price elastic to their own price and the prices of China's soybean imports from both Argentina and Brazil. China's soybean imports from Argentina were price

elastic to their own price and the price of soybean imports from the United States. China's soybean imports from Brazil are not affected by any price.

4.8. Future Research

This paper applied the differential production model to investigate China's soybean imports from different source countries. The estimation results imply that there are other topics worth more research in the future.

The estimation results suggest that China's domestic soybean meal price, but not soybean oil price, significantly affected this country's soybean imports. Moreover, soybean meal is not a final product as it is used as animal feed in China's meat industry. Therefore, it is natural to ask whether prices in China influenced its soybean imports.

The own price coefficient of soybean imports from Argentina in the import demand system is positive (Table 4.5). Moreover, in the total expenditure equations (Table 4.6 and Table 4.10), the import price coefficients for Argentina are significantly positive too. This leads to significantly positive unconditional own price elasticities of China's soybean imports from Argentina (Table 4.8 and Table 4.10) and may be inconsistent with theory. The estimation results suggest taking into account both soybean meal and oil as outputs. Argentina supplied 81 percent of China's soybean oil imports in 2006/2007 (USDA, FAS, 2008a). A differential production model that specifically studies China's soybean oil imports should be established to investigate a more complete role of Argentina in China's soybeans and soybean product imports.

That only soybean meal significantly affected China's soybean imports was rooted in the feature of China's domestic crushing industry, whose crushing capacity is 80 MMT every year, but its usage is around 40 MMT. It might be possible that China's domestic soybean industry will crush more soybeans domestically in future years. If changes in the current marketing system of China's soybean products are very likely in the future, it will be important to forecast how these changes will affect China's soybean imports from different source countries.

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Appendix A: Unit Roots Test

To test a unit root is to test the hypothesis $H_0 : \gamma = 0$ under the framework of the augmented Dickey-Fuller (ADF) form, that is:

(A.1) $$\Delta y_t = a_0 + \gamma y_{t-1} + a_1 t + \sum_{t=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$$

The problem is that the actual data-generating process is unknown. When the estimated regression includes at least all the deterministic elements in the actual data-generating process, the distribution of γ is non-normal under the null hypothesis $H_0 : \gamma = 0$. When the estimated regression includes deterministic regressors that are not in the actual data-generating process, the power of unit root test decreases. On the other hand, if a deterministic regressor that exists in the actual data-generating process is omitted in the estimated regression, the power of the test goes to zero as the sample size increases. The details of these difficulties in testing unit roots are reported in Campbell and Perron (1991).

Enders (1995) proposes a four-step procedure to test unit roots to avoid the above problems. The procedure is stated below:

Step 1. Estimate

(A.1) $$\Delta y_t = a_0 + \gamma y_{t-1} + a_1 t + \sum_{t=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$$

Use the τ_τ statistic (the statistic table is on p.419, Enders 1995) to test the null hypothesis $H_0 : \gamma = 0$. If the null hypothesis is rejected, it is concluded that y_t doesn't contain a unit root and the procedure stops. If the null hypothesis is not rejected, go to step 2.

Step 2. If the null hypothesis $H_0 : \gamma = 0$ is not rejected, use the ϕ_3 statistic (the statistic table is on p.421, Enders 1995) to test the null hypothesis $H_0 : a_1 = \gamma = 0$. If the null hypothesis is rejected, retest the null hypothesis $H_0 : \gamma = 0$ using the standardized normal distribution. If the null hypothesis is rejected, it is concluded that y_t doesn't contain a unit root and the procedures stops. Otherwise, it is concluded that y_t contains a unit root and stop. If the null hypothesis $H_0 : a_1 = \gamma = 0$ is not rejected, go to step 3.

Step 3. Estimate

(A.2) $\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{t=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$

Use the τ_μ statistic (the statistic table is on p.419, Enders 1995) to test the null hypothesis $H_0 : \gamma = 0$. If the null hypothesis is rejected, it is concluded that y_t doesn't contain a unit root. If the null hypothesis is not rejected, use the ϕ_1 statistic (the statistic table is on p.421, Enders 1995) to test the null hypothesis $H_0 : a_0 = \gamma = 0$. If the hypothesis is rejected, retest the null hypothesis $H_0 : \gamma = 0$ using the standardized normal distribution. If the null hypothesis is rejected, it is concluded that y_t doesn't contain a unit root and the procedure stops. If the null hypothesis is not rejected, it is concluded that y_t contains a unit root and the procedure stops. If the null hypothesis $a_0 = \gamma = 0$ is not rejected, go to step 4.

Step 4. Estimate

(A.3) $\Delta y_t = \gamma y_{t-1} + \sum_{t=2}^{p} \beta_i \Delta y_{t-i+1} + \varepsilon_t$

Use the τ statistic (the statistic table is on p.419, Enders 1995) to test the null hypothesis $H_0 : \gamma = 0$. If the null hypothesis is rejected, it is concluded that y_t doesn't contain a unit root and the procedure stops. If the null hypothesis is not rejected, it is concluded that y_t contains a unit root and the procedure stops.

This four-step procedure begins with the least restrictive form, equation (A.1), with both intercept and deterministic trend included and encompasses simpler forms in equations (A.2) and (A.3). This procedure is applied to test unit roots in the summer flounder monthly price, quantity and substitute quantities (for both original and log transformed data). The four-step procedure is explained using an example of the summer flounder monthly price in the original data form.

In order to set up ARIMA models for the summer flounder price, three different methods, Extended Sample Autocorrelation Function (ESACF, Tsay and Tiao 1984), Minimum Information Criterion (MINIC, Hannan and Tissannen 1982), and Smallest Canonical (SCAN, Tsay and Tiao 1985), were applied in Section 2.6.1 to find out tentative combinations of autoregressive (AR) and moving-average (MA) orders for the data. The tentative combinations of AR and MA order for both original and log transformed monthly summer flounder price data are contained in Table A1. The first number in parenthesis represents the AR order, and the second number represents MA order in error term.

Table A1. Tentative Orders for Estimating ARIMA Models of Summer Flounder Price

	Tentative ARIMA Orders
Original Price	(1,0), (2,1), (4,2), (0,3), (1,3), (1,5)
Log Transformed Price	(1,0), (3,2), (0,3)

For example, (1,0) in the first row means that the tentative AR order of the original price is 1 and the data doesn't contain moving average order. Another combination (2,1) in the first row means that the tentative AR order of the original price is 2 and the tentative MA order of it is 1. The combination (3,2) in the second row means that the tentative AR order of the log transformed price is 3 and the tentative MA order of it is 2. Although the Equation (2.20) used to test unit roots doesn't contain MA order in error term, Said and Dickey (1984) suggests that an unknown ARIMA $(p,1,q)$ process can be well approximated by an ARIMA $(n,1,0)$ autoregression of order no more than $T^{1/3}$, where n and p is the order of autoregression in y_t, 1 represents one unit root in y_t, and q is the order of moving averages in error term. Because the number of observations in this project is 168 and, in approximation, n should not be more than $T^{1/3}$, the tentative order of autoregression is 5.

Next, the four-step procedure is applied to test unit roots in the original summer flounder monthly price with tentative order (1,0) and (5,0), where the latter is an approximation of all combinations containing nonzero MA orders in error term.

Tentative Order (1,0): AR order of the original price is 1

Step 1. Estimate

$$\Delta fsp_t = a_0 + \gamma\, fsp_{t-1} + a_1 t + \varepsilon_t$$

, where: a_0 is an intercept, fsp_t is the monthly price of summer flounder, Δfsp_t is the first order difference of fsp_t, t is a deterministic trend, and ε_t is an independently identically-distributed (i.i.d.) error. Test the null hypothesis $H_0 : \gamma = 0$. The τ_τ-statistic for H_0 is –6.86, and the critical value on the statistic table (Enders 1995, p.419) is –3.45 with a significance level of 5%. The null hypothesis is rejected. It is concluded that fsp_t doesn't contain a unit root and the procedure stops.

Tentative Order (5,0): AR order of the original price is 5

Step 1. Estimate

$$\Delta fsp_t = a_0 + \gamma fsp_{t-1} + a_1 t + \sum_{i=1}^{4} \beta_i \Delta fsp_{t-i} + \varepsilon_t$$

Test the null hypothesis $H_0 : \gamma = 0$. The τ_τ -statistic is –2.62, and the critical value for H_0 on the statistic table (Enders 1995, p.419) is –3.45 with a significance level of 5%. The null hypothesis is not rejected. Go to step 2.

Step 2. Test the null hypothesis $H_0 : a_1 = \gamma = 0$. The ϕ_3 statistic for H_0 is 15.0817, and the critical value on the statistic table (Enders 1995, p.421) is 6.49 with a significance level of 5%. So, $H_0 : a_1 = \gamma = 0$ is not rejected. Retest the null hypothesis $H_0 : \gamma = 0$ using the standardized normal distribution. The t -statistic is –2.62 and the critical value for $H_0 : \gamma = 0$ is –1.65 with a significance level of 5%. The null hypothesis $H_0 : \gamma = 0$ is rejected and it is concluded that y_t doesn't contain a unit root and the procedure stops.

Therefore, it is concluded that, for both tentative autoregressive orders (1,0) and (5,0), the monthly price of summer flounder doesn't contain a unit root.

Appendix B: Violation of the Second Order Condition

Results in Table 3.8 indicate that the revenue maximization can't be solved optimally for market shares from years 1999, 2004 and 2005. In order to find the season, the second order condition is checked for all models with market shares from different years and their average. In checking it, since the Hessian matrix is diagonal in this model, only the signs of the diagonal elements need to be checked. In other words, check if the inequality (12) holds for all twelve months or not. The results are contained in Table B1.

Table B1. Values of the Second Order Condition Checks for the Optimization Problems with Market Shares from 1991 to 2005 and Their Average

	2005	2004	2003	2002	2001	2000	1999	1998
Jan	-5.1E+05	-4.3E+05	-4.5E+05	-4.1E+05	-3.7E+05	-3.6E+05	5.5E+11	-2.0E+05
Feb	5.8E+11	5.2E+11	-3.2E+05	-5.5E+05	-6.6E+05	-4.5E+05	-5.5E+05	-6.3E+05
Mar	-1.0E+06	-6.5E+05	-6.1E+05	-8.8E+05	-1.0E+06	-9.9E+05	-9.7E+05	-1.0E+06
Apr	-8.6E+05	-6.7E+04	-1.1E+06	-9.6E+05	-1.1E+06	-1.1E+06	-2.3E+04	-1.1E+06
May	-8.8E+05	-9.7E+05	-7.7E+05	-8.5E+05	-8.4E+05	-8.4E+05	-8.0E+05	-8.2E+05
Jun	-8.3E+05	-7.7E+05	-6.2E+05	-6.0E+05	-6.6E+05	-6.2E+05	-7.6E+05	-6.7E+05
Jul	-4.6E+04	-7.3E+05	-7.4E+05	-7.4E+05	-7.4E+05	-6.7E+05	-8.9E+05	-7.9E+05
Aug	-8.3E+05	-8.0E+05	-6.7E+05	-6.3E+05	-6.7E+05	-6.9E+05	-8.8E+05	-7.5E+05
Sep	-6.7E+05	-8.6E+05	-7.6E+05	-6.4E+05	-5.7E+05	-6.6E+05	-9.6E+05	-6.7E+05
Oct	-8.4E+02	-8.0E+05	-8.3E+05	-7.4E+05	-6.6E+05	-7.7E+05	-6.4E+05	-6.9E+05
Nov	-4.3E+05	-4.9E+05	-4.5E+05	-4.0E+05	-4.5E+05	-4.8E+05	-5.1E+05	-3.9E+05
Dec	-5.3E+05	-5.8E+05	-5.5E+05	-6.2E+05	-5.9E+05	-6.1E+05	-7.6E+05	-5.0E+05

	1997	1996	1995	1994	1993	1992	1991	Average 91 to 05
Jan	-1.5E+05	-3.1E+05	-2.8E+05	-4.6E+05	-4.7E+05	-4.7E+05	-4.4E+05	-4.6E+05
Feb	-7.8E+05	-2.3E+05	-5.8E+05	-4.3E+05	-6.1E+05	-5.8E+05	-5.0E+05	-3.2E+05
Mar	-9.1E+05	-1.1E+06	-8.0E+05	-7.6E+05	-7.2E+05	-7.9E+05	-8.9E+05	-6.3E+05
Apr	-9.9E+05	-1.2E+06	-1.0E+06	-1.0E+06	-1.1E+06	-9.2E+05	-1.1E+06	-1.1E+06
May	-8.0E+05	-8.1E+05	-8.2E+05	-7.8E+05	-8.0E+05	-8.2E+05	-9.0E+05	-7.9E+05
Jun	-5.8E+05	-6.2E+05	-6.5E+05	-6.3E+05	-6.6E+05	-6.9E+05	-6.8E+05	-6.3E+05
Jul	-7.3E+05	-8.1E+05	-8.3E+05	-8.4E+05	-8.6E+05	-8.8E+05	-8.6E+05	-7.6E+05
Aug	-7.1E+05	-6.3E+05	-6.6E+05	-6.8E+05	-7.4E+05	-7.6E+05	-7.6E+05	-6.9E+05
Sep	-6.4E+05	-4.6E+05	-6.5E+05	-5.7E+05	-6.9E+05	-7.2E+05	-7.6E+05	-7.8E+05
Oct	-5.9E+05	-5.9E+05	-5.9E+05	-5.1E+05	-5.9E+05	-6.0E+05	-6.9E+05	-8.4E+05
Nov	-5.5E+05	-6.2E+05	-4.6E+05	-4.8E+05	-5.1E+05	-5.1E+05	-5.0E+05	-4.6E+05
Dec	-8.2E+05	-8.3E+05	-5.7E+05	-6.5E+05	-6.9E+05	-5.9E+05	-5.8E+05	-5.7E+05

For models using 2005 and 2004 market shares, the inequality doesn't hold in February and for 1999, it doesn't hold in January. So, the three models have non-optimal solutions. As to models using all other year market shares and the average one of 1991 to 2005, the inequality holds for all twelve months.

Appendix C: Zero Percent in May and August in Fisherman B's Estimates

To study the effects of zero percent of landing of May and August in *Fisherman B*'s estimates, and to examine the sensitivity of the structures of the optimization model, three extensions are generated. The optimization results are contained in Table C1. The upper part of the table contains the monthly landing quantities of summer flounder for each extension, and the lower part of the table contains the monthly real prices of the fish for each extension. The model *Extension One* is designed to study the changes in optimization revenue if the months May and August are removed from the *One Constraint* scenario, which doesn't contain any biological constraints, except the total annual quota constraint. *Extension One* then is a ten decision-making-variable model. The optimized revenue in the *One Constraint* model is $12.35 million, which is higher than that of $11.51 million in *Extension One*. This indicates that revenue will decrease if nothing is caught in May and August. Similar to *Extension One*, the model *Extension Two* is a ten-month model. However, *Extension Two* is transformed from the model *Fisherman B*, where landing percentages in May and August are zero. The *Extension Two* solution implies that the fish could be caught in 9 months with zero pounds landing in December. The optimized landing quantities and prices of *Extension Two* are the same as those in the model of *Fisherman B*. The optimized annual revenue is $11.11 million. So, the two different approaches of keeping quantities in May and August at zero (*Fisherman B)* or removing them from the model (*Extension Two*) give the same results in the final optimized landing quantities and revenue. Lastly, since the optimized landing is zero in December in *Extension Two*, the month December is removed in *Extension Three*.

Table C1. Maximized Annual Revenue, Optimized Monthly Landings and Prices for Summer Flounder in 2007 using the Substitutes' Quantities at 2005 level and the *Average Market Shares* from 1991 to 2005, *One Constraint Scenario vs. Fishermen Estimates and Extensions*

Monthly Landings of Summer Flounder (One Million Pounds)					
	One Constraint	Fisherman B	Extension One	Extension Two	Extension Three
Jan	0.443	0.629	0.563	0.629	0.629
Feb	0.641	0.954	0.84	0.954	0.954
Mar	1.069	1.416	1.298	1.416	1.416
Apr	1.285	1.641	1.523	1.641	1.641
May	1.026	0	Removed	Removed	Removed
Jun	0.803	1.041	0.962	1.041	1.041
Jul	0.981	1.317	1.205	1.317	1.317
Aug	0.875	0	Removed	Removed	Removed
Sep	0.832	1.165	1.051	1.165	1.165
Oct	0.843	1.161	1.052	1.161	1.161
Nov	0.597	0.846	0.76	0.846	0.846
Dec	0.777	0	0.917	0	Removed
Monthly Real Prices of Summer Flounder ($/Pound)					
	One Constraint	Fisherman B	Extension One	Extension Two	Extension Three
Jan	1.669	1.398	1.477	1.398	1.398
Feb	1.336	1.144	1.2	1.144	1.144
Mar	1.309	1.172	1.213	1.172	1.172
Apr	1.204	1.106	1.135	1.106	1.106
May	1.247	0	Removed	Removed	Removed
Jun	1.102	1.022	1.046	1.022	1.022
Jul	1.071	0.99	1.014	0.99	0.99
Aug	1.154	0	Removed	Removed	Removed
Sep	1.119	1.014	1.045	1.014	1.014
Oct	1.211	1.085	1.123	1.085	1.085
Nov	1.124	1.014	1.047	1.014	1.014
Dec	1.237	0	1.165	0	Removed
Revenue (One Million Dollars)	**12.35**	**11.11**	**11.51**	**11.11**	**11.11**

Not surprisingly, the final results in *Extension Three* are the same as those from *Extension Two* and *Fisherman B*. It is concluded that (1) the annual revenue will decrease if nothing is caught in May and August; (2) if nothing is caught in May and August, it will be optimal to catch nothing in December also. That the results of the models of *Fisherman B*, *Extension Two*, and *Extension Three* are identical is at least a partial verification that the revenue maximization model is operating correctly.