ANALYSES OF U.S. DEMAND FOR FRESH TROPICAL FRUIT AND VEGETABLE IMPORTS

by

KILUNGU NZAKU

(Under the Direction of Jack E. Houston)

ABSTRACT

Since the 1970s, the demand for fresh fruits and vegetables have been on the rise, due to increased purchasing power of U.S. consumers as personal incomes increased, changing U.S. consumer perceptions and habits towards consuming more fresh fruits and vegetables for better health, and a fast growing population of immigrants who are accustomed to fresh-produce diets. Limitations in climate and farm labor supply also hampered U.S. producers’ ability to respond to the increased demand. As a result, the U.S. increasingly depends on imports from NAFTA, banana-exporting countries, and the Southern-Hemisphere to satisfy the demand for fresh produce. The growing demand for fresh fruit and vegetable imports in the U.S., combined with the lack of exhaustive studies on U.S. demand for fresh produce imports, forms the basis for this study.

This study analyzes the demand for tropical fresh fruit and vegetable imports into the U.S. and explores the demand relationships between the fresh fruits and vegetables from various sources using a source-differentiated Almost Ideal Demand System approach. The analysis shows that seasonality affects the demand for tropical fresh fruit and vegetable imports. Further, all the commodities in the analysis have a positive and significant trend except for bananas.
NAFTA has no apparent impact on tropical fresh fruits, because they originate from tropical regions, but it does impact fresh vegetable imports.

Our results confirm that most tropical fresh fruits are luxury commodities, while bananas are a staple food. Bananas face strong competition from other tropical fresh fruits. With the exception of asparagus, all the fresh vegetable imports significantly compete with domestically grown fresh vegetables, which support prior studies particularly on fierce competition between Florida tomatoes and imports from Mexico and Canadian greenhouse. Fresh imported grapes also compete with U.S. domestically produced fresh grapes instead of complementing each other. Results also indicated that U.S. consumers have a preference for tropical fresh fruits from various sources due to quality differences. For example, Guatemalan bananas, Costa Rican pineapples, and the ROW papayas and mangoes/guavas are preferred over the same commodities from competing countries.

A major policy implication of this study is that the U.S. may need to re-examine the impact of fresh vegetable imports on the domestic fresh produce industry as they are not contra-seasonal and pose a threat to domestic producers. The evidence from this study shows that fresh vegetable imports are significant substitutes with locally produced fresh vegetables and the same for fresh grapes. International fresh fruit and vegetable trade players and countries of origin could use the results from the study to determine their export promotion strategies in the U.S. fresh produce market based on their commodity’s expenditure, own-price and cross-price elasticities.

INDEX WORDS: Fresh Tropical Fruit and Vegetable Imports, Source-Differentiated AIDS Model, Error Correction
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To my beloved parents Nzaku Iswii and Jospina Mukai. To my late grandmother Mary Mbithe Mbindyo. Lastly, to my mentor, the late Dr. Gerald A. Mumma
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1.1. **Background Information:**

In the past three decades, U.S. imports of fresh fruits and vegetables have steadily increased. According to a United States Department of Agriculture (USDA) reports, (Huang and Huang 2007) between 1990-92 and 2004-06, annual U.S. imports of fresh produce, which include both fresh fruits and vegetables, rose from U.S. 67 million to U.S. 77.8 million constant dollars. The share of total U.S. imports from agriculture for fresh fruits and vegetables expanded from 11.5 percent to 13.3 percent within the same period (Huang and Huang 2007). Concurrently, U.S. domestic production of fresh produce increased less rapidly, and as a result the U.S. became a net importer of fresh produce (Huang and Huang 2007).

The substantial growth in U.S. fresh fruit and vegetable imports could be partially attributed to factors such as rising consumer incomes, influx of immigrant population to the United States, international trade agreements, improved technology, and high labor costs (Martin and Thompson 1992; Huang and Huang 2007). Increasing consumer incomes has led to more consumption of fresh fruits and vegetables, while the introduction of more trade agreements with major producing countries has increased the availability of imports. At the same time, there has been a substantial improvement in technology, particularly in the shipping and handling of fresh produce. The improved technology has resulted in a significant extension of shelf life of fresh produce, making it easier to fill the gaps in U.S. domestic production (Huang and Huang 2007).
Most of the fresh produce production is labor-intensive. With farm labor limitations and the high costs of labor in the U.S., this makes labor charges the biggest proportion of the U.S. fresh produce production costs (Biermacher et al. 2007; Fonsah and Guilhamoulat 2004; Fonsah 2006a). Although globally, fresh produce production is labor-intensive as well, labor is far much less expensive and more available in the less developed countries compared to U.S., making fresh production from some of these countries cheaper than in the U.S. This constantly creates an opportunity for importing cheaper fresh fruits and vegetables, as well as, an influx of immigrant farm workers to keep U.S. fresh produce production competitive (Martin and Thompson 1992; Escalante 2006).

Another factor contributing to rising fruit and vegetable imports is the effect of increasing awareness of the health benefits of consuming diets high in fruits and vegetables among American consumers. As a result, Americans are increasingly consuming more total and per capita fruits and vegetables than previously. There is also the effect of increasing Asian and Hispanic immigrant populations with a heavy fresh-produce diet culture (Dimitri, Tegene, and Kaufman 2003).

Geography has played a major role in the global trade patterns of fresh produce due to the fact that fresh produce is very perishable and seasonal in production. Sanitary and Phytosanitary (SPS) measures to control the spread of pests and diseases are increasingly becoming a critical factor in determining trading partners (U.S. Department of Agriculture). Here, the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (APHIS) plays a very important role to ensure that only healthy commodities are imported into the United States. This is done through phytosanitary certificates, importation rules and inspections (U.S. Department of Agriculture). Phytosanitary restrictions might be one of the reasons why there are relatively few
suppliers for fresh produce imports in the U.S. Other factors, such as cost of production, transportation costs, and climate factors, product demand, and to some extent, marketing orders by the USDA’s Agricultural Marketing service also affect imports (U.S. Department of Agriculture).

The U.S. fresh produce industry is dominated by a few regions. Fresh vegetable imports from North American Free Trade Agreement partners (NAFTA) comprise the single largest trade flow of fresh produce into the U.S and exceed $31.5 million in real dollars. Fresh vegetable trade with the U.S. is largely concentrated in NAFTA and Asia – 95 percent of U.S. exports and 84 percent of U.S. imports. On the other hand, U.S. fruit trade is more diverse than vegetable trade and is less significant in those regions – 85 percent of U.S. exports and 28 percent of U.S. imports (Huang and Huang 2007).

The main sources of U.S. fresh fruit imports are the so-called “banana-exporting countries”, the southern hemisphere countries, and NAFTA partners. The banana exporting countries include Colombia, Costa Rica, Ecuador, Guatemala, Honduras and Panama (Huang and Huang 2007). The name originates from an attempt in 1974 by these countries, who where then the major exporters of bananas to the United States, to form a cartel. Fresh fruit exports to the U.S. from these countries amount to 36 percent of the countries’ total exports, of which two-thirds are bananas. Second to banana-exporting countries in supplying U.S. fresh fruit imports are Southern Hemisphere countries, which include Argentina, Australia, Brazil, Chile, New Zealand, South Africa, and Peru. These countries supply 32 percent of U.S. fresh fruit imports. NAFTA is the third main source of fresh fruit imports to the U.S. and comprises approximately 27 percent of the total fresh fruit imports. Most of NAFTA’s contribution to U.S. fresh fruit
imports is by Mexico as Canada does not significantly supply the U.S. with fresh fruits. The remainder of fresh fruit imports, come from the rest of the world (Huang and Huang 2007).

Two thirds of the value of U.S. fresh fruit imports are bananas, grapes and tropical fruits, of which 44 percent are bananas. Tropical fruits refer to a variety of fresh fruits that, due to climatic factors, are grown mainly in tropical regions. In this case tropical fresh fruits include pineapples, papayas, and avocados. Technically, bananas are tropical fruits as well, but because they compose the bulk of fresh fruit imports, they are normally counted separately from the rest of the tropical commodities. Banana imports peaked in 1999 generating on average $1.1 billion import value and stabilized thereafter (Fonsah et al. 2007; Fonsah, Krewer, and Rieger 2005; Fonsah 2003). However, the value share of bananas in the U.S. fresh fruit import mix has declined over the years as a result of significant entry of more varieties of fresh fruits, mostly tropical fruits, than ever before (Huang and Huang 2007). Besides bananas, the major tropical fresh fruit imports include pineapples, mangoes, papayas, and guavas particularly.

Compared to total domestic consumption, U.S. fruit and vegetable imports are relatively substantial and overshadow domestic production. As fresh fruit and vegetable imports continue to grow considerably, their impacts on domestic producers cannot be ignored.

1.2. Problem Statement and Justification

The demand for fresh fruits and vegetables has increased tremendously in the U.S since the 1970’s, especially demand for tropical fresh produce. Although the demand for domestic fresh fruits and vegetables has been increasing for the last two decades, domestic supply for tropical fruits and vegetables have been restricted due to an unfavorable U.S. continental climate, seasonal nature of production, and U.S. farm labor limitations and costs (Biermacher et al. 2007; Fonsah 2007). This has led the country to increasingly rely on importation of tropical fresh
produce from other countries, particularly from the tropics, to satisfy demand. At the same time, the rise in imports of fresh fruits and vegetables is playing a major role in the increased consumption of fresh produce. For example, in 2003-05, imports accounted for approximately 44 percent of fresh fruit and vegetable consumption. This trend is bound to continue as consumer awareness on healthy diets continues to grow (Fonsah 2004a; Huang and Huang 2007). Indeed, the total fruit consumption is predicted to grow by 24-27 percent by 2020 because of increased per capita consumption and 50 million more consumers in the U.S. Per capita fruit consumption is predicted to grow between 5 and 8 percent because of higher income, aging of the U.S. population, higher educational achievement, and the influx of Hispanics and Asians, Africans, and the Caribbean Islanders (Guthrie 2004; Huang and Huang 2007).

While studies have been conducted on the competitiveness of U.S. farm produce within the country and in the major destinations of U.S. fruit and vegetable exports (Andayani and Tilley 1997; Feleke 2006; Lee, Seale, and Jierwiriyapant 1990; Sparks 1992), little has been studied on the U.S. importation of fresh fruits and vegetables. Some of the available literature have studied demand for imported fruit juices (Fonsah and Muhammad 2008), while others have examined the overall demand for fruits and vegetables (Arnade, Pick, and Gehlhar 2004, 2005; You, Epperson, and Huang 1998). There is a need to understand the market for those products, the competitiveness exhibited by the supplying countries, as well as the seasonality effects to demand, especially for tropical fresh produce. If, for instance, the tropical fresh products demonstrate a decrease in marginal consumption of one product with an increased consumption of another, which implies that the products are substitutes, a competitive market exists. However, if they demonstrate an increase or no change in their marginal consumption with an increase in consumption of another, then they are complements or independent of each other and this is a non-competing market.
By assessing the competitiveness of tropical fruits and vegetables in the U.S., this study highlights crucial implications to exporters’ (countries of origin) marketing strategies. Based on the results, a country of origin could decide to embark on market promotion, product differentiation or expansion or contraction of supply. A presence of non-competitive market products could warrant opening up the U.S. tropical fresh produce market to more countries to increase competition and improve consumer welfare (Fonsah 2005, 2006c).

Model specification and estimation of demand systems are often central means in the analysis of food consumption. This is because they provide estimates of price and income elasticities and demand forecasts, and therefore the quest for better and more reliable estimation methods are likely to continue. A common finding that most economic time series data are nonstationary with a unit root is a cause for likely cointegration (Attfield 1997; Edgerton et al. 1996; Engle and Granger 1987; Huang and Lin 2000; Karagiannis, Katranidis, and Velentzas 2000; Karagiannis and Mergos 2002; Van Heeswijk, De Boer, and Harkema 1993). In such a scenario, the estimation of a vector error correction model (ECM) is required. An ECM would make elasticity estimates more reliable than in the case of least square estimation and therefore improve demand forecasts. Such a dynamic analysis of the U.S. demand for fresh produce imports through an ECM is a departure from the traditional models (Henneberry et al. 1990; Henneberry and Hwang 2007; Karagiannis, Katranidis, and Velentzas 2000; Karagiannis and Mergos 2002).

This study addresses some key research questions on food demand systems analysis. The first question is how different tropical fresh products from different countries compete in the U.S. market for fresh produce? Secondly, do the nonstationary properties of the time series data to be used in the analysis affect elasticity estimates, and if so, how?
1.3. Purpose of the Study

The purpose of this study is to analyze U.S. demand for fresh tropical fruits and vegetables from the major supplying countries. The products selected for this study include bananas, pineapples, avocados, papayas, grapes, mangoes and guavas for tropical fresh fruits, and peppers, tomatoes, cucumbers, and asparagus for fresh vegetables. These commodities were selected based on the top fresh fruit imports and data availability. For fresh fruits commodities were selected if their import share of consumption is 50 percent or more. Fresh vegetables with the highest import growth rate (over 50 percent) were selected subject to data availability. Using a restricted, source-differentiated AIDS (Almost Ideal Demand System) model, the study assesses the market competitiveness of tropical fresh fruits and vegetable imports into the U.S. The findings from this study are expected to help shape U.S. trade policies on tropical fresh produce importation. The major countries that supply the U.S with fresh produce and the rest of the world (ROW) are selected for the analysis. To capture the seasonality of fresh produce production and supply effects on the demand for tropical fresh produce, a dynamic AIDS model is estimated using monthly data for the period January 1989 through December 2008.

1.4. Study Objectives

The general objective of this research is to analyze the demand relationship for fresh produce imports into the United States of America. The study seeks to address the following specific objectives:

(i) Examine the seasonality, trends, and patterns of U.S. demand for tropical fresh fruit and vegetable imports;
(ii) Assess the competitiveness of the demand for tropical fresh fruits and vegetables from different countries of origin by estimating a source-differentiated AIDS model;

(iii) Estimate the elasticities of demand for U.S. tropical fresh fruit and vegetables.

(iv) Identify the dynamic trends affecting U.S. demand for imported fresh fruits and vegetables by estimating a dynamic AIDS model and source differentiated AIDS (SDAIDS) model; and,

(v) Draw trade and market policy implications for the U.S. and for countries of origin for fresh produce from the results of the study.

1.5. Organization.

The remainder of this dissertation is organized in chapters as follows. In Chapter 2, a literature review on tropical fresh fruit and vegetable trade trends is discussed followed by a detailed presentation of theoretical and model approaches to demand analysis. The main body of the dissertation is presented in Chapters 3, 4, 5, and 6. Chapter 3 presents the estimation of a trigonometric AIDS model of U.S. demand for fresh fruits and vegetables that captures seasonality effects. A dynamic estimation of AIDS model (ECM version) of tropical fresh fruits and vegetables together with the respective results discussion is presented in Chapters 4 and 5 respectively. A source-differentiated AIDS model estimation of tropical fresh fruits is presented in Chapter 6 followed by a brief comparison of results from the chapters 3, 4, and 5, an overall summary, conclusions, and a discussion of the limitations of the study in chapter 7. Finally, seasonal import quantities and expenditure shares of the analyzed fresh fruit and vegetable imports and a glossary of the key terms used throughout the study are presented in the Appendices.
CHAPTER 2
LITERATURE AND THEORETICAL FRAMEWORK

2.1 Introduction

This chapter presents a review of the existing literature, particularly fresh tropical fruits and vegetable production, distribution, consumption and trade in the world and in the U.S. The chapter also includes import demand analysis approaches and the theoretical framework employed in the study.

2.2 Global Fresh Fruit and Vegetable Trade Trends

Worldwide, three regions - the European Union (EU), NAFTA, and Asia (East, South, and Southeast) - are the major destinations and major sources of supply for fruit and vegetable trade. These regions depend on the Southern Hemisphere countries for imports of juices (Fonsah and Muhammad 2008) and off-season fresh fruits and on equatorial regions for bananas. In 2007 China alone produced 37% of the world’s fruit and vegetables (Fonsah 2008). From 1990 to 2000 the EU imported 58% of the world’s fresh vegetables whereas the NAFTA regional market imported 23% (Fonsah 2004b, 2004a). In 2004, the EU was the leading destination and source of global fruit and vegetable trade and accounted for 50 percent of the world imports and 40 percent of world exports. Most of the EU’s trade is intraregional, except for fresh fruits, which mostly involve substantial imports from geographically proximate partners and former colonies under preferential trade agreements (Fonsah and Chidebelu 1995; Huang 2004).
Developing countries contribute 98 percent of total global production of fresh tropical fruits while developed countries account for 80 percent of world import trade (United Nations 2003a, 2003b). Mango fruit dominates tropical fruit production worldwide, followed by pineapples, papaya, and avocado. Approximately 75 percent of global tropical fruit production is mango fruit.

According to Food and Agriculture Organization (FAO), bananas are the most exported fresh fruit in both volume and value and the fourth most important crop in the world in terms of food security. They can be used in different ways such as staple food, medicinal purposes, desert, ornamental and even for purees, beer, liquor and decoration (United Nations n.d.). Bananas are produced in more than 123 countries throughout the world (Paggi and Spreen 2003) and play a major role in the economies of developing countries in all tropical regions and subtropical regions. The largest producers of bananas are India and Brazil but most of their production is consumed domestically due to quality problems (Fonsah 2003a). World banana trade grew in volume for decades but the rate of growth declined in the 1990 and the trade value reached a peak between 1997 and 1999 as a result of declining prices in the U.S. (United Nations n.d.).

The bulk of the banana production is concentrated in about 10 countries that account for 63 percent of the total world production. These countries in the order of production volume are India, Brazil, Ecuador, China, the Philippines, Indonesia, Costa Rica, Thailand, Mexico and Colombia. In Brazil, India, China and Indonesia, bananas are staple food commodities while in Ecuador, Colombia, Costa Rica, and the Windward Islands bananas are primarily an export crop (Paggi and Spreen 2003).
More than half of bananas produced globally are consumed in the world's main banana producing countries. India, Brazil, China, U.S. and the E.U. are the leading consumers of bananas (Paggi and Spreen 2003). Global trade in bananas has been steadily increasing in quantity and value in the past years with 94 percent of exports originating from 10 countries. Ecuador, Costa Rica, Colombia, the Philippines, Guatemala, Panama and Honduras account for 88 percent of the world's exports. The U.S. and the E.U. are the leading import markets for bananas (Paggi and Spreen 2003).

The challenge to supply seasonal and perishable products year-round has favored imports and increased horizontal and vertical integration among shippers regionally, nationally and internationally. No country produces all the fresh fruits and vegetables it demands on a daily or weekly basis, thus creating an opportunity for trade. Other countries are responding to the U.S. market’s growing demand for imports by aggressively developing their horticultural industries consistent with the implementation of broader export-led economic growth and diversification strategies. The U.S. is one of the dominant players in the international horticultural trade both as an importer and exporter of world horticultural trade and also the largest net importer of banana the world over (Cook 2001).

Most domestic fruit and vegetable production in the U.S. is seasonal with the largest harvest occurring during the summer and fall (Lucier et al. 2006). Seasonality in the production and consumption of perishable commodities and natural climatic production advantages, are the driving forces behind fresh fruit and vegetable trade. Trade is often contra-seasonal, such as the importation of Southern Hemisphere grapes and avocados from Chile into the U.S. during the winter and spring to meet demand when domestic supply is slow. Similarly, the U.S. imports grapes from Mexico in the winter but exports the same to Mexico in the fall. A desirable feature
of contra-seasonal demand is that it is complementary and non-contentious. Contentious trade occurs when differing levels of competitiveness occur between producers of the same or similar product as in the case of Mexican extended-shelf-life tomato imports competing with Florida mature green tomatoes (Cook 2001; Lucier et al. 2006; Lucier, Pollack., and Perez. 1997).

Since the 1970’s, demographic and lifestyle trends have segmented the U.S. market causing an increase in the diversity of consumers and the products they demand. Fresh produce consumption has been favorably affected by numerous demographic trends, including declining household size, rising income levels, the consumption habits of baby boomers, and an ethnicity. Studies have demonstrated that spending on fresh fruit and vegetables is higher for households with middle-age and older members (Cook 2001; Nayga 1995; Guthrie 2004). People in these age-groups have more disposable income to spend on the often more expensive fresh fruits and vegetables, and they tend to increase their consumption of these products due to the reported health benefits (Fonsah 2004a). The aging of the U.S. baby-boom population and the increase in the life expectancy of Americans appear to have boosted demand for fresh fruits and vegetables. The ethnicity composition of the U.S. population has also significantly changed due to the influx of Asian and Hispanic populations through immigration. These ethnic groups are known to consume of fresh produce foods and are a major driving force behind the growing in fresh fruit and vegetable consumption (Guthrie 2004).

The fresh produce market has also changed remarkably over the last 15 years. Shifts in consumer demand, technological advancement in production and marketing, and retail consolidation, have altered the traditional relationships between producers, wholesalers, and retailers (Dimitri, Tegene, and Kaufman 2003). Americans have been consuming more fruits and vegetables over the last three decades. Specifically, in 2005 per capita total fruit and vegetable
consumption (fresh and processed) reached 687 pounds up 110 pounds (19 percent) since 1970 (Wells and Buzby 2008). As shown in Table 2.1, consumers are eating more fresh produce, purchasing a wider variety year round, and demanding convenience (Dimitri, Tegene, and Kaufman 2003; Wells and Buzby 2008; U.S. Department of Agriculture 2009). Per capita consumption of fresh fruits and vegetables rose from 121 pounds and 162 pounds in 1987 to 162.2 pounds and 202.2 pounds in 2007 respectively (U.S. Department of Agriculture 2009). Per capita consumption of fresh fruits and vegetables increased by 6 percent between 1987 and 1995, 8 percent between 1995 and 2000, and 11.7 percent between 2000 and 2007. As consumption has increased, so has the demand for variety and quality (Dimitri, Tegene, and Kaufman 2003).

<table>
<thead>
<tr>
<th></th>
<th>Pounds of Consumption Per Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Fruits</td>
<td>121</td>
</tr>
<tr>
<td>Fresh Vegetables</td>
<td>162</td>
</tr>
<tr>
<td>Total</td>
<td>283</td>
</tr>
</tbody>
</table>

Source: USDA, NASS, Per Capita Consumption of Major Food Commodities Publications 2009

Information technology has introduced efficiencies throughout the supply chain reducing production and marketing costs. Mass merchandisers and warehouse club retailers are selling bigger volumes of food products with low-price strategies. Fresh fruits and vegetables sold to restaurants, food outlets, and other foodservice operators have grown to about more than half of all retail produce sales (Huang 2004; Huang and Huang 2007, 2007).

The U.S. is a major producer and exporter of many fruits and vegetables. U.S. fruit and vegetable production is concentrated among the Southern and Pacific Coast States. California
and Florida and Georgia states dominate the U.S. vegetable and fruit production. Imports of fresh
truits and vegetables into the U.S. have expanded rapidly since 1980, when they amounted to 8.2
billion pounds and accounted for 15.4 percent share of total consumption. In 1996, imports were
16.8 billion pounds amounting to 21 percent of the total fresh fruits and vegetables consumed in
the U.S. Since then, fresh fruit and vegetable imports have continued to grow (Cook 2001;

2.3 U.S. Fresh Fruit and Vegetable Imports

The main sources of U.S. fresh fruit imports are the banana exporting countries, the
Southern Hemisphere and NAFTA (Table 2.2). The banana-exporting countries include:
Colombia, Costa Rica, Ecuador, Guatemala, Honduras, and Panama. According to the USDA
reports, these countries together provide 36 percent of the total U.S. fresh fruit imports. More
than three-quarters of the fresh fruit value exported to the U.S. from these countries are bananas.
The Southern Hemisphere countries provide approximately 32 percent of U.S. fresh fruit
imports. These countries include of Argentina, Australia, Brazil, Chile, New Zealand, South
Africa, and Peru. The NAFTA countries, which include Mexico and Canada, provide 27 percent
of U.S. fresh fruit imports (Fonsah 2003b; Huang 2004; Huang and Huang 2007). However,
most of fresh fruit supplies from NAFTA are mainly from Mexico. In contrast, most of fresh
vegetable imports are from NAFTA with Mexico supplying the bulk (64 percent) of the value of
U.S. fresh vegetable imports and Canada accounting for 19 percent (Huang and Huang 2007).

Bananas, tropical fruits (mangoes, guavas, papayas, pineapples, and avocados), and
grapes are the major fresh fruits that account for fresh fruit imports with bananas representing
almost half of the value of fresh fruit imports. The graph in Figure 2.1 shows the import value
growth of non-traditional fresh fruits in the U.S. between 1990 through 2006. While import
values of bananas were steady, those of fresh grapes and tropical fresh fruits grew by approximately 300 and 700 percent respectively implying a tremendous increase in demand. Fresh tropical fruits recorded the largest growth in import value followed by fresh grapes.

Table 2.2. Major trade flows of U.S. fresh fruit and vegetables, average and nominal dollars, 2004-2006.

<table>
<thead>
<tr>
<th>Produce Value</th>
<th>Destination of exports</th>
<th>European Union</th>
<th>NAFTA</th>
<th>Asia</th>
<th>Southern Hemisphere</th>
<th>Banana exporting countries</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export Fresh fruit</td>
<td>$ Million</td>
<td>6.1</td>
<td>44.8</td>
<td>40.1</td>
<td>2.8</td>
<td>1.7</td>
<td>4.5</td>
<td>100</td>
</tr>
<tr>
<td>Fresh Vegetables</td>
<td>$ Million</td>
<td>2.2</td>
<td>83.8</td>
<td>10.8</td>
<td>0.8</td>
<td>0.1</td>
<td>2.8</td>
<td>100</td>
</tr>
<tr>
<td>Origin of Imports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Export Fresh fruit</td>
<td>$ Million</td>
<td>2.8</td>
<td>26.5</td>
<td>1.1</td>
<td>32.3</td>
<td>35.6</td>
<td>1.7</td>
<td>100</td>
</tr>
<tr>
<td>Fresh Vegetables</td>
<td>$ Million</td>
<td>2.7</td>
<td>82.8</td>
<td>1.6</td>
<td>4.1</td>
<td>6.7</td>
<td>2.1</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: USDA, ERS, 2007

Figure 2.1. Import value growth of nontraditional fresh fruit, 1990 - 2006

Source: USDA, ERS, 2007
Three fresh vegetables account for 60 percent of the total value of fresh vegetable imports: tomatoes (19 percent), peppers (18 percent), and cucumbers (10 percent). For these fresh vegetables, import values have been steadily increasing since 1990. The graph in Figure 2.2 below shows the import value growth of the top three U.S. vegetable imports from 1990 through 2006. Since 1994, the import values of fresh tomatoes, peppers, and cucumbers rose significantly. The import value of fresh peppers, tomatoes, cucumbers and gherkins is shown to have grown by over, 400, 300, and 200 percent respectively within this period.

**Figure 2.2. Import value growth of the top three U.S. vegetable imports, 1990 – 2006**

![Graph showing import value growth of top three U.S. vegetable imports, 1990-2006.](source: USDA, ERS, 2007)

The graph in Figure 2.3 emphasizes the importance of tropical fresh fruit imports in the U.S. consumption of fresh fruits. It shows U.S. major fresh fruit imports as a percentage of domestic consumption of fruits from 1989 through 2006. During this period, bananas and mangoes/guavas imports constituted 100 percent of U.S. domestic consumption. Fresh pineapples and papayas imports accounted for less that 50 percent of domestic consumption in the beginning of 1989 but increased drastically to over 80 percent by 1995. Avocado imports
accounted for approximately 10 percent of domestic consumption but increased to nearly 60 percent by 2006 (Fig 2.3).

**Figure 2.3. U.S. Fresh Fruit Imports as a Percent of Domestic Consumption, 1989-2006**


2.4 Economic Theory and Models

Common approaches to import demand analysis involve the use of consumer demand theory and production theory. The consumer demand theory approach treats imports as final products that directly enter a consumer’s utility function (Schmitz and Seale 2002). This approach enables the derivation of traditional consumer demand and labor supply functions from utility maximization. On the other hand, production theory treats imports as inputs (Washington and Kilmer 2002). This makes it possible to derive input demand and output supply functions from profit maximization or cost minimization.
The major difference between the production approach and the consumer demand approach is that output functions are derived in the production approach while labor supply functions are derived in the consumer demand approach. Also, the parameter estimates of unconditional demand and unconditional input demand are different. Nevertheless, in both approaches, the parameter estimates are similar, and, according to Goodwin (1994), assuming constant percentage of retail price type of marketing margin, the demand for any given quantity of product is equally elastic (or inelastic) with respect to price at all market levels.

**The Production Approach**

This approach involves making two allocation decisions, one involving outputs and the other involving inputs. The decision making may be successive or simultaneous, through a two-step profit maximization or one-step/direct profit maximization procedure, yielding a system of output supply and input demand functions (Washington and Kilmer 2002; Feleke 2006). The two-step profit maximization procedure is made by deciding on output quantities given output and input prices. Once the output quantity is planned, the input quantities needed to produce the planned output is decided upon. In the simultaneous decision, input and output decisions are not independent of each other and according to Laitinen (1978), their error terms are correlated. The input demand cannot be estimated independently of the output supply function and vice versa. Once the output supply and conditional input demand are estimated, the unconditional demand parameters can be derived from the parameters of the two functions (Washington and Kilmer 2002; Feleke 2006).

According to Theil (1980), the input allocation decisions involving the use of conditional input demand functions can be implemented in two stages. First, total expenditure is allocated
over broader groups of inputs and then group expenditures are allocated over individual inputs within each group. This approach is comparable to the two-stage utility maximization of the consumer demand approach.

The production approach may be realistic for broadly defined groups of imported goods such as food, crude materials, semi-manufactures, and finished manufactures under the input independence assumption. However, when dealing with narrowly defined products such as tropical fresh produce, it is not conceptually defensible to apply the production approach. This is because the importing firm’s production function of an imported fresh produce is independent of other imported fresh produce.

**Consumer Demand Approach**

Consumer theory is amenable to analysis of demand for tropical fruits and vegetables. The theory involves analysis of the changes in marginal utilities of a product due to a change in consumption of a closely related product. The changes in marginal utilities are due to price substitution effects in the demand functions. From the utility functions, Marshallian demand functions can be derived.

**Utility Maximization**

Consumer theory assumes that the most straightforward way to generate demand equations is to derive them by maximizing the utility function subject to the consumer’s budget constraint. The utility framework forms the foundation for index number theory, which includes the measurements of real income, the measurement of the effects of distortions such as commodity taxation, and the division of commodities into closely related groups. Utility
functions generate three major restrictions of analysis: (1) homogeneous demand functions; (2) the symmetric substitution effects; and (3) negative semidefinite substitution matrix. The direct utility function is expressed (Varian 1992; Wetzstein 2005) as

$$U = u(q_k)$$  \hspace{1cm} (2.1)

where \( q_k \) is the quantity consumed of good \( k \) and \( U \) is the utility derived from consuming good \( k \). The utility is maximized subject to a linear budget constraint

$$\sum_{k=1}^{n} p_k q_k = x,$$  \hspace{1cm} (2.2)

\( k = 1, ..., n \)

\( p_k \) is the price of the \( k^{th} \) good, and \( x \) is income or total expenditure. The utility maximization theory assumes that the utility function is differentiable and that there is nonsatiation, thus implying a positive marginal utility. That is,

$$\frac{\partial u(q_k)}{\partial q_k} > 0$$

A system of Marshallian demand functions for goods \( q_k \) can be derived from constrained utility maximization by the Lagrange method (Varian 1992; Wetzstein 2005; Perloff 2008) as

$$L(q, \lambda) = u(q_k) = u(q_1, ..., q_n) + \lambda(x - \sum_{k=1}^{n} p_k q_k)$$  \hspace{1cm} (2.3)

where \( \lambda \) denotes the Lagrangian multiplier interpreted as the marginal utility of income. The first-order conditions with respect to \( q_k \) and \( \lambda \) yield

$$\frac{\partial L(q, \lambda)}{\partial q_k} = \frac{\partial u(q_k)}{\partial q_k} - \lambda p_k, \text{ and}$$  \hspace{1cm} (2.4)

$$\frac{\partial L(q, \lambda)}{\partial \lambda} = x - \sum_{k=1}^{n} p_k q_k.$$  \hspace{1cm} (2.5)
These first order conditions constitute \( n+1 \) equations, and can be solved for \( n+1 \) unknowns \( q_1, q_2, \ldots, q_n \) and \( \lambda \). The resulting quantities are unique and positive for relevant values of prices and income. The optimal quantities depend on income and prices. The solution is a system of Marshallian demand functions denoted by

\[
q_k = q(p_1, \ldots, p_n, x), \text{ and} \tag{2.6}
\]

the Lagrange multiplier, \( \lambda \), written as,

\[
\lambda = \lambda(p_1, \ldots, p_n, x) \tag{2.7}
\]

The Lagrange multiplier is interpreted as the marginal utility of money. It is the amount by which the maximized value of utility would increase given a unit relaxation in the constraint.

**Indirect Utility Maximization**

By substituting the Marshallian demand functions into the utility function presented earlier in equation (2.1), one can derive the indirect utility function (Varian 1992) as

\[
U^* = u(q_k(x, p_k)) = U_1(x, p_k) \tag{2.8}
\]

where \( q_k \) and \( p_k \) are vectors of \( n \) quantities and prices, and function \( U_1(x, p_k) \) is the indirect utility function.

The indirect utility function represents the maximum utility attainable given prices and total expenditure (income). In other words, the indirect utility function has price and total expenditure as arguments. The indirect utility function is continuous at all prices and total expenditure, and also it is non-increasing in prices and non-decreasing in income. It is also quasi-concave and homogeneous of degree zero in prices.
Roy (1942) provided a theorem (Roy’s Identity) with a second way to generate demand system equations from indirect utility functions (Wetzstein 2005; Varian 1992; Perloff 2008). Given an indirect utility function, Roy’s identity is given by,

\[ q_k = -\frac{\partial u_i}{\partial p_k} / \frac{\partial u_i}{\partial x} \tag{2.9} \]

provided that the right hand side is well defined and that \( p_k > 0 \) and \( m > 0 \). Christensen, Jorgenson and Lau (Christensen, Jorgenson, and Lau) used the Roy’s Identity to introduce the translog indirect utility function to generate the translog demand system (Deaton and Muellbauer 1993).

**Cost Minimization and Consumer Demand**

Previously we formulated the consumer’s problem as maximizing utility for a given outlay or cost. We can reformulate the problem as one of selecting goods to minimize the outlay necessary to reach a selected level of utility. The chosen goods must be the same in both cases; hence, a dual problem exists.

The duality approach of demand theory posits that consumers minimize their expenditure of achieving a fixed level of utility. This optimization leads to the cost function which is also referred to as the expenditure function and is expressed as a function of utility and prices. The function can be obtained by inverting the indirect utility function and then solving for income. An equivalent definition is given (Varian 1992) as

\[ c(u, p) = \text{Minimize } pq \text{ subject to } u(q) = u \tag{2.10} \]

A key property of the cost function is Shephard’s lemma, which states that

\[ \frac{\partial C}{\partial p_k} = q_k = h(U, p_k) \tag{2.11} \]
This property provides a third approach to derive demand functions by specifying the cost function form and then applying the Shephard’s lemma. These are called Hicksian demand functions. They tell us how quantities demanded are affected by prices with the level of utility held constant and therefore are called compensated demand functions. The Hicksian demand functions are unobservable, since they are expressed as a function of unobservable U. This approach of generating demand equations was used by Deaton and Muellbauer (1980).

**Differential Demand System Approach**

A different approach to generate demand equations is the differential approach taken separately by Barten (1965) and Theil (1965) to formulate the Rotterdam model. The differential approach does not require algebraic specifications of the utility function, the indirect utility function, or the cost function. The solution of a fundamental matrix equation is applied to derive a general system of differential demand equations.

From Marshallian demand equations (2.6), we can obtain the total differential demand equations as

\[
d_q = \frac{\partial q_k}{\partial x} dx + \sum_{j=1}^{n} \frac{\partial q_k}{\partial p_j} dp_j
\]  

Equation (2.12) can then be transformed to logarithmic differential form by multiplying both sides by \( \frac{p_k}{x} \) and using budget shares, \( w_k = \frac{p_k q_k}{x} \)

\[
w_k (\log q_k) = \frac{\partial p_k q_k}{\partial x} d(\log x) + \sum_{j=1}^{n} \frac{p_k q_k}{x} \frac{\partial q_k}{\partial p_j} d(\log p_j)
\]  

Equation (2.13) can be further simplified by applying the Slutsky equation. The Slutsky equation is,
\[ \frac{\partial q_k}{\partial p_j} = s_{ij} - q_j \left( \frac{\partial q_k}{\partial x} \right), \quad (2.14) \]

and the substitution effect, \( s_{ij} \) in equation (2.14) can be decomposed into two terms. That is,

\[ \frac{\partial q_k}{\partial p_j} = \lambda U_j^k - \lambda \left( \frac{\partial q_k}{\partial \lambda} \right) \left( \frac{\partial q_j}{\partial \lambda} \right) - q_j \frac{\partial q_k}{\partial x} \quad (2.15) \]

where the first term on the right-hand side is the specific substitution effect, the second term is the general substitution effect and the last term is the income effect.

Substituting (2.15) into (2.13), we obtain

\[ w_i d(\log q_k) = \left( \frac{\partial (p_k q_k)}{\partial x} \right) \left[ d(\log x) - \sum w_j d(\log p_j) \right] + \sum_j \left[ \left( \frac{\lambda p_k p_j U_{kj}}{x} \right) - \left( \frac{\lambda}{x} \right) \left( \frac{\partial (p_k q_k)}{\partial x} \right) \left( \frac{\partial (p_j q_j)}{\partial x} \right) \right] d(\log p_j). \quad (2.16) \]

For simplification, let's define

\[ \phi = \left( \frac{\lambda}{x} \right) \left( \frac{\partial \log \lambda}{\partial \log x} \right) < 0. \]

Which is the reciprocal of income elasticity of marginal utility of income, also known as Frisch’s money flexibility. We also define

\[ \theta_{kj} = \frac{\lambda}{\phi x} p_k p_j U_{kj}, \]

which satisfies

\[ \sum_j \theta_{kj} = \left( \frac{\lambda}{x} \right) \left( \frac{\partial \lambda}{\partial x} \right) \left( \frac{x}{\lambda} \right) p_k \sum_j p_j U_{kj} = \beta_k. \]

Thus, equation (2.16) can be written as the differential demand equation for good \( k \) as
\[ w_k d(\log q_k) = \theta_k d(\log Q) + \phi \sum_{j=1}^{n} \theta_{kj} d(\log \frac{p_j}{P}) \]  \hspace{1cm} (2.17)

where \( d(\log Q) \) is the Divisia volume index and \( d(\log P) \) is the Frisch price index.

**Properties of Demand Functions**

Deaton and Muellbauer (1993) reviewed the properties of consumer demand which provide reasonable restrictions to demand models. In many empirical works, these restrictions have been tested to confirm the theoretical validity of estimated demand functions. One of the most important properties of demand functions is adding up, which is given by

\[ \sum_{k=1}^{n} p_k h_k(up) = \sum_{k=1}^{n} p_k f_k(p, x) = x \]  \hspace{1cm} (2.18)

This implies that the estimated total value of both the Hicksian and Marshallian demands is equal to the total expenditures. The sum of the total expenditures on the different goods must equal the total expenditure (income) at a given period. This property provides the so-called adding-up restriction property (Deaton and Muellbauer 1993) and implies that

\[ \sum_k p_k \frac{\partial q_k}{\partial x} = 0 \approx \sum_k w_k e_k = 1 \]  \hspace{1cm} (2.19)

where \( w_k \) is the budget share of good \( k \) and \( e_k \) is the total expenditure elasticity. This implies that the marginal propensities to consume should sum up to one.

The second property is homogeneity of degree zero in prices and total expenditures for uncompensated demand. This implies that if income and all prices are changed by an equal proportion, the quantity demanded must remain unchanged. Sometimes this is called the absence of money illusion, and it provides the homogeneity restriction that, for \( k = 1, 2, \ldots, n \),

\[ w_k \]
\[
\sum_k p_k \frac{\partial q_i}{\partial p_k} + x \frac{\partial q_i}{\partial x} = 0 \approx \sum_k e_{ik} + e_i = 0
\]  \hspace{1cm} (2.20)

where \( \sum_k e_{ik} + e_i \) is the sum of the own price elasticity and cross-price elasticities of the \( i \)th good.

Third is the cross-price derivative symmetry property of the Hicksian demand. This is denoted by,

\[
\frac{\partial h_k(u, p)}{\partial p_j} = \frac{\partial h_j(u, p)}{\partial p_k} \text{ for all } i \neq j
\]  \hspace{1cm} (2.21)

The symmetry property can be proven through Shephard’s lemma and Young’s theorem. The Shephard’s lemma is stated as:

\[
h_k(u, p) = \partial^c(u, p)/\partial p_k, \quad h_j(u, p) = \partial^c(u, p)/\partial p_j
\]

\[
\frac{\partial h_k(u, p)}{\partial p_j} = \frac{\partial^2 c}{\partial p_k \partial p_j}, \quad \frac{\partial h_j(u, p)}{\partial p_k} = \frac{\partial^2 c}{\partial p_j \partial p_k}, \quad (2.22)
\]

and Young’s theorem, is

\[
\frac{\partial^2 c}{\partial p_k \partial p_j} = \frac{\partial^2 c}{\partial p_j \partial p_k}
\]  \hspace{1cm} (2.23)

The fourth theoretical property of demand functions is that the matrix formed by the element \( \partial h_k/\partial p_j \) is negative semidefinite. This implies downward sloping compensated demand functions.

**Model Choices**

The choice of a functional form must satisfy the economic properties and satisfactorily fit to statistical data. Fousekis and Revell (2000) identify two steps to be followed in demand specification. The first step is to impose behavioral assumptions, which lead to a cost function or
an indirect utility function, and the second is to select a parsimonious and flexible functional form.

The Armington trade model was the most commonly used demand model that dominated import demand literature in the past. Its application to trade data dates back to the late 1970’s and was very popular in the 1980’s and 1990’s (Alston et al. 1990; Babula 1987; Duffy, Wohlgenant, and Richardson 1990). However, the model came under intense criticism based on conceptual and empirical grounds. There was evidence that data may not support the hypothesis of separability and homotheticity, and traditional methods of implementing the Armington model of trade resulted in theoretically and statistically inconsistent estimates (Alston et al. 1990; Davis and Kruse 1993). Consequently, system-wide demand models such as the Rotterdam model and the Almost Ideal Demand Systems, have come to be popular in the most recent import demand literature (Zhang, Fletcher, and Carley 1994; Clements and Theil 1978; Henneberry and Hwang 2007; Lee, Seale, and Jierwiriyapant 1990; Schmitz and Seale 2002; Seale, Sparks, and Buxton 1992; Soshnin, Tomek, and Gorter 1999; Washington and Kilmer 2002; Yang and Koo 1994).

Demand and price studies have been the cornerstone of applied research in consumer demand theory and in developing demand models for consumer goods (Abdallah, Ghaffar, and Poerwono 1994). Before the works of Stone (1954) with the Linear Expenditure System (LES), demand analysis was solely based on single equation estimations and no emphasis was made on basic theory.

Some of the more commonly used demand system models include the Rotterdam Model (Barten 1977; Theil 1980) and the Translog Model (Christensen, Jorgenson, and Lau 1975). The latest of these models is the Almost Ideal Demand System (AIDS) and its derivatives introduced
by Deaton and Muellbauer (1980) to overcome the LES limitation of imposing substitutions among commodities (Blanciforti and Green 1983).

**The Almost Ideal Demand System model**

The AIDS model builds on the previous work of Working (1943) and Leser (1963). The model begins with the formulation of Engel curves in terms of expenditure shares. The AIDS demand function for the $i^{th}$ commodity can be described as follows (Deaton and Muellbauer 1980, 1993):

$$w_i = \alpha_i + \sum \gamma_{ij} \ln p_k + \beta_i \ln(y / P) + u_i$$  \hspace{1cm} (2.24)

where $w_i$ is the expenditure share of good $i$, $y$ is total expenditure, and $u_i$ denotes the disturbance term. $P$ is a price index defined as

$$\ln P = \alpha^0 + \sum_k \alpha_k \ln p_k + \frac{1}{2} \sum_k \sum_j \gamma_{ij} \ln p_i p_j .$$  \hspace{1cm} (2.25)

To be consistent with consumer demand theory, we must ensure that the following necessary conditions hold:

$$\Sigma \alpha_k = 1 , \quad \Sigma \gamma_{ij} = 0 , \quad \text{and} \quad \Sigma \beta_k = 0 \quad \text{(adding-up property)}$$  \hspace{1cm} (2.26)

$$\Sigma \gamma_{ij} = 0 : \text{(homogeneity property), and}$$  \hspace{1cm} (2.27)

$$\gamma_{ij} = \gamma_{jk} : \text{(symmetry property)}$$  \hspace{1cm} (2.27)

These conditions ensure that the demand system satisfies adding-up, homogeneity in prices and income and Slutsky symmetry. In the AIDS model, $\alpha_i$ is the intercept and represents the estimated budget share of commodity $i$ when all logarithmic prices and real expenditures are zero interpreted as subsistence expenditure. $\beta_i$’s are expenditure coefficients and represent the marginal budget share or the change in commodity $i$’s expenditure share with respect to change...
in real income, *ceteris paribus*. If $\beta_i > 0$, then that commodity is a luxury, and if $\beta_i < 0$, the good is a necessity. Expenditure shares $w_i$, therefore, increase with an increase in total expenditure if $\beta_i > 0$ and decrease if $\beta_i < 0$. The price coefficients, $\gamma_{ij}$, represent the change in the $i$th budget share with respect to a percentage change in the $j$th price with real expenditures held constant. If $\gamma_{ij} > 0$, goods $i$ and $j$ are substitutes, while if $\gamma_{ij} < 0$, they are complementary goods.

The price index discussed above poses empirical estimation challenges to the AIDS model owing to the nonlinearity in its second term. Empirical estimation choices include either linearizing the model, which in some cases could result in biased price coefficients (Hahn 1994; Green and Alston 1990; Green and J. Alston 1991), or estimating the model in its unbiased nonlinear form.

**Source-Differentiated AIDS Model**

Applications of the AIDS model to import demand often assume either product aggregation or block separability (Henneberry and Hwang 2007; Yang and Koo 1994). Under the aggregation assumption, products are perceived as the same irrespective of their sources. On the other hand, block separability assumptions allow estimation of share equations for products from different sources (Alston et al. 1990; Andayani and Tilley 1997). A source-differentiated AIDS (SDAIDS) model allows for commodity source differentiation without imposing block separability (Henneberry and Hwang 2007). This is a more general model that does not impose perfect substitutability. Because of this quality, the major advantage of the SDAIDS model is that it is free from aggregation bias across import sources or products.

The SDAIDS specification follows Henneberry and Hwang (2007), and Yang and Koo (1994) as
\[ w_{ih} = \alpha_{ih} + \sum_j \sum_k \gamma_{ihjk} \ln(p_{jk}) + \beta_{ih} \ln\left(\frac{E}{P^*}\right) \]  
\[ h = 1, 2, 3, ..., m \text{ and } k = 1, 2, 3, ..., n \]

where, \( i \) and \( j \) represent commodities, and \( h \) and \( k \) indicate countries of origin for the goods. Commodity \( i \) may be imported from \( m \) different sources and \( j \) may be from \( n \) different sources. \( w_{ih} \) is the budget share of good \( i \) imported from source \( h \) and \( p_{jk} \) is the price of good \( j \) imported from source \( k \). \( E \) denotes the total expenditure on all the goods in the demand system, while \( P^* \) is a price index defined as

\[ \ln P^* = \alpha_0 + \sum_i \sum_h \alpha_i \ln(p_{ih}) + \frac{1}{2} \sum_i \sum_h \sum_j \sum_k \gamma_{ihjk} \ln(p_{ih}) \ln(p_{jk}) \]  
\[ (2.30) \]

As mentioned under the AIDS model, the index \( P^* \) is nonlinear, which makes the SDAIDS model nonlinear, also. Several alternative forms can be used to transform the system to a linear approximation. These include a regular price index proposed by Moschini (1994), the Tornquist index, the “corrected” Stone index, and the geometrically weighted average of prices (Moschini 1994, 1995; Moschini and Meilke 1989).

The Stone’s price index suggested by Deaton and Muellbauer (1980, 1993) is specified as

\[ \ln P^* = \sum_i \sum_h w_{ih} \ln(p_{ih}) \]  
\[ (2.31) \]

and may introduce a simultaneous equation bias, because \( w_{ih} \) is used both as a dependent variable in the demand system and an independent variable in the price index expression. This simultaneity problem can be solved by lagging \( w_{ih} \) in the Stone price index as suggested by Eales and Unnevehr (1988) such that the new Stone index becomes

\[ \ln P^* = \sum_h w_{ih,t} \ln(p_{ih}) \]  
\[ (2.32) \]
Another intriguing setback of Stone’s price index is that it fails to meet a fundamental
property of index numbers, in Diewert’s (1987) words, the “commensurate” property. This arises
from the fact that the index is arbitrary and variant to the choice of units of measurement for the
prices and quantities described by Moschini (1995). This problem can be addressed by
approximating the price index $P^*$ by the index $P'$, which is invariant to changes in the units of
measurement up to a multiplicative constant, $P'(p) = \kappa P'(\bar{p})$. $\kappa$ is an arbitrary constant and
therefore any changes in the unit of measurements only affects the intercept of the linear AIDS
model and the price parameters remain unaffected. However, when $\kappa=1$, the indices will be
invariant to changes in units of measurement.

According to Yang and Koo (1994), a better option is to use Tornqvist index, which is a
superlative index of the translog function and is a discrete approximation to the Divisia index,
expressed as

$$\ln P^T_t = \frac{1}{2} \sum_{i=1}^n \left( w_i + w_i^0 \right) \ln \left( \frac{p_{it}}{p_i^0} \right) \tag{2.33}$$

with $0$ denoting values for the base period, $t$ denoting current period values, and $T$ represents
the period under consideration.

The “corrected” Stone index, on the other hand, is a loglinear analogue of the Paasche
price index, according to Moschini (1995) and is similar to employing the Stone index expressed
in (2.31). This becomes the case either when prices are themselves indices, such as the case of
Deaton and Muellbauer, or when prices are scaled by their means, as in Moschini and Meilke
(1989). The “corrected” Stone index is expressed as

$$\ln P^S_t = \sum_{i=1}^n w_i \ln \left( \frac{p_{it}}{p_i^0} \right) \tag{2.34}$$
Replacing the current share values, \( w_i \), in the “corrected” Stone index with the base share values, one obtains the geometrically weighted average price index. This index does not change with changes in units of measurement up to a multiplicative constant, allowing further simplification necessary for an approximating index. The geometrically weighted average index is written as

\[
\ln P_i^C = \sum_{i=1}^{n} w_i^0 \ln(p_i^c) \quad (2.35)
\]

This index is an analogue of the Laspeyres price index.

Estimating SDAIDS in equation (2.29) in the absence of sufficient observations can result in unreliable results. The SDAIDS contains all the product prices of different goods from different sources in every equation. Given \( n \) commodities originating from \( m \) sources (countries), the number of estimated parameters for each equation is \( n^2m + 2n \), which is likely to lead to a degrees of freedom problem. To circumvent this limitation, we can impose a restriction as in Yang and Koo (1994) that

\[
\gamma_{i,k} = \gamma_{i,j} \quad \forall k \neq j
\]

which implies that the cross-price effects are not source differentiated between products but are differentiated within a product. For instance, U.S. demand for Mexican mangoes have no source differentiated cross-price effects with demand for Chilean pineapples and other countries, but they do have source-differentiated cross-price effects with demand for mangoes from Chile or other countries. This assumption helps to reduce the number of parameters to be estimated, resulting in the following restricted SDAIDS (RSDAIDS) model:

\[
w_i = \alpha_i + \sum_k \gamma_{i,k} \ln(p_{ik}) + \sum_{j\neq i} \gamma_{i,j} \ln(p_{ij}) + \beta_i \ln \left( \frac{E}{P^r} \right) \quad (2.36)
\]
Dynamic AIDS Model

The AIDS model discussed so far can be classified amongst static demand models. The model shows the relationship between budget shares, prices, and expenditures as a contemporary relationship. Although popular, this model over time has faced challenges because of the poor quality of aggregate data, functional misspecification of demand systems, and inappropriate estimation techniques (Karagiannis and Mergos 2002). Until recently, the model has been ignoring dynamic specification in time series analysis. Recent studies have pointed out that inconsistency between theory and data in demand analysis could be related to modeling data of time-series nature (Karagiannis and Mergos 2002; Van Heeswijk, De Boer, and Harkema 1993; Edgerton et al. 1996). Notably, the import shares will not only be conditioned on current values of the explanatory variables, but also on the season and past values of import deliveries which the AIDS model ignores. If monthly data is used for analysis, we expect lag effects to be strong. Accounting for some of these statistical properties is likely to offer a better approach in specifying U.S. tropical fresh fruit and vegetables import demand systems.

Using cointegration analysis, Ng (1995) showed that homogeneity holds in many cases, while Attfield (1997) found that homogeneity holds when applying a triangular correction procedure to the AIDS model. Balcombe and Davis (Balcombe and Davis 1996) also proposed a canonical cointegrating regression procedure for estimating an AIDS model if prices follow a distributed lag process or seasonality is present.

More recently, Karagiannis, Katranidis, and Velentzas (2000) brought up the possibility and potential of using an error correction model (ECM) of the AIDS model. The ECM approach is based on the view that a long-run equilibrium cointegrating demand system may exist that captures long-run effects of prices and income on demand for fresh produce. Fluctuations in
prices and income, and new information, might disrupt the equilibrium and the adjustment process may be incomplete at any single period of time. During these periods, consumption is out of equilibrium and short-run responses to changes in price and income may provide insufficient insight into their long-run effects.

Introducing time into the linear AIDS model presented earlier in equation (2.24), we write the model as follows:

\[ w_{it} = \alpha_{it} + \sum_{j=1}^{J} \gamma_{ij} \ln p_{jt} + \beta_{it} \ln(y_i / P_t) + u_{it} \]  

(2.37)

where \( w_{it} \) is the budget share of the \( i \)th commodity at time \( t = 1,...,T \), \( p_{jt} \) is the price of \( j \)th commodity at \( t \), \( y_i \) is the total expenditure on imports, \( u_{it} \) is the disturbance term for equation \( i \) at time period \( t \). \( P_t \) represents the aggregate price index at time period \( t \). Notice that this model assumes that consumers are always in equilibrium. In reality, habit persistence, adjustment costs, imperfect information and incorrect expectations interfere with instant expenditure adjustment to prices and income changes (Anderson and Blundell 1983). It is expected that the data are nonstationary and presence of unit roots is likely to invalidate the asymptotic distribution of the estimators(Karagiannis, Katranidis, and Velentzas 2000; Karagiannis and Mergos 2002; Van Heeswijk, De Boer, and Harkema 1993). In the event this problem occurs, the disturbances are serially correlated, traditional test statistics are unreliable and least squares estimation of the model is spurious.

The properties of the time-series data have to be determined so that an appropriate dynamic model can be specified. Karagiannis and Mergos (2002) suggest that the number of unit roots should be determined for each time series either by Dickey-Fuller, the augmented Dickey-Fuller, the Philips-Perron, or the Johansen test. This means that budget shares, prices and total
expenditures must be tested for unit roots (Edgerton et al. 1996; Karagiannis, Katranidis, and Velentzas 2000; Karagiannis and Mergos 2002).

Based on the order of integration of the relevant series, three alternative approaches can be applied. In the first approach, if all the variables are integrated of same or different order, the cointegrated regression equation can be written in an error correction model (ECM) form. A second approach is to use ECM even when the variables have different time series properties based on the Granger representation theorem (Karagiannis and Mergos 2002). The Granger representation theorem states that a cointegrated vector autoregressive process can be decomposed into four components: a random walk, a stationary process, a deterministic part, and a term that depends on the initial values, Engle and Granger (1987). The random walk and the deterministic component are important for the asymptotic analysis of the cointegration process (Hansen 2005).

However, given the low power of cointegration tests, Banerjee, Dolado, and Smith (1986) and Kremers, Ericson and Dolado, (1992) suggested a third method of testing for cointegration whenever the previous two alternatives failed. They suggest formulating and estimating an ECM, and then testing for the significance of the error correction term. If the null hypothesis that the coefficient of the error correcting term is not significantly different from zero is not rejected, then the series is not cointegrated (Karagiannis and Mergos 2002). However, if the null hypothesis is rejected, then the series is cointegrated.

If cointegration is found in the series, the linear AIDS model has to be estimated as an ECM, as shown in numerous studies for food and meat products (Attfield 1997; Balcombe and Davis 1996; Karagiannis, Katranidis, and Velentzas 2000; Karagiannis and Mergos 2002; Edgerton et al. 1996). Following Karagiannis and Mergos (2002) and Van Heeswijk, De Boer, and Harkema (1993), the ECM- linear AIDS model is given by
\[ \Delta w_i = \delta_i \Delta w_{t-1} + \sum_{j=1}^{n} \gamma_j \Delta \ln p_j + \beta_i \Delta \ln (Y/P) + \lambda_i \mu_{u_{t-1}} + u_i \] (2.38)

where \( \Delta \) denotes the difference operator, \( u_{u_{t-1}} \) are the lagged estimated residual from cointegration equations, and \( \lambda_i \) is the error correction term. The term \( \delta_i \) is the deviation of actual budget shares in the previous period, \( w_{t-1} \). In the current period \( t \), consumers attempt to change current budget share \( w_i \) from its value in the previous period (i.e., \( w_{t-1} \)) and try to close the gap between the previous observed budget share \( w_{t-1} \) and the previously desired budget share \( w^*_{t-1} \).

These adjustments move budget shares in the direction of the desired values and eventually establish a long-run equilibrium. Estimation of (2.38) is done by seemingly unrelated regression (SUR), which adjusts for cross-equation contemporaneous correlation. It is also important to note that, the theoretical restrictions of adding-up, homogeneity, and symmetry can be satisfied.
CHAPTER 3
A TRIGONOMETRICAL AIDS MODEL ESTIMATION OF U.S. FRESH FRUIT AND VEGETABLE IMPORTS

3.1 Introduction

Since the 1970s, U.S. demand for fresh fruits and vegetables, especially the demand for tropical fruits and vegetables has increased greatly. This growth in demand has been attributed to rising consumer incomes and an increasing consumer awareness of the health benefits of eating diets that are heavy in fresh produce (Lucier, Pollack, and Perez. 1997; Wells and Buzby 2008; Pollack 2001). This is due to the effect of a growing U.S. population of recent immigrants, particularly Asians and Hispanics, that is accustomed to fresh produce meals (Guthrie 2004).

In response to the rising demand for fresh fruits and vegetables, domestic production has risen, but not at the same rate as the increase in demand, mainly due to the unfavorable U.S. continental climate, seasonality in production, and high domestic farm labor costs (Huang and Huang 2007; Martin and Thompson 1992; Cook 2001; Fonsah 2004a, 2004b, 2004c). As a result, the U.S. has increasingly become more dependent on imports to satisfy demand (Huang and Huang 2007). Between 1990-92 and 2004-06, annual U.S. imports of fresh fruits and vegetables rose from 67 million to 77.8 million constant U.S. dollars. The share of total U.S. imports from agriculture for fresh fruits and vegetables increased from 11.5 percent to 13.3 percent for the same period. By the year 2003-05, imports accounted for 44 percent of fresh fruit and vegetable consumption (Huang and Huang 2007) and at the moment, the U.S. is a net importer of fresh fruits.
Although the demand for all fresh fruit and vegetable imports rose in general over the last three decades, most of the growth was for tropical fresh fruits and vegetables. The main tropical fresh fruit imports include bananas, mangoes/guavas, papaya, pineapples, avocados, and fresh grapes. Fresh tomatoes, cucumbers and gherkins, peppers, and asparagus, on the other hand, dominate U.S. fresh vegetable imports. Of these commodities, mangoes/guavas, papayas, avocados, fresh grapes, tomatoes, cucumbers, and peppers have recorded the highest growth in imports since early 1990. The value of imports of pineapples, mangoes, guavas, papayas, and avocados was six times greater in 2006 compared to 1990. Import values for grapes grew by over 350 percent from 1990 to 2006. Fresh bananas, which comprise the bulk of fresh fruit imports, showed no significant growth, and its import value was stable for the entire period (Huang and Huang 2007). During the same period, the import value of fresh bell peppers, tomatoes, and cucumbers and gherkins grew by over 400, 300, and 250 percent, respectively (Huang and Huang 2007).

The significance of imports in U.S. consumption of tropical fresh fruits grew substantially from 1989 to 2006. Nearly all of the mangoes/guavas and bananas consumed in the U.S. are imported. The import shares of fresh papayas and pineapples also drastically increased from slightly less than 50 percent in 1989 to over 80 percent in 2006. Avocado imports accounted for nearly 60 percent of U.S. domestic consumption in 2006 compared to 10 percent in 1989 (U.S. Department of Agriculture 2007).

U.S. fresh fruit and vegetable import supply is dominated by a few regions, perhaps due to high transport costs, the perishable nature of fresh produce commodities, and sanitary and phytosanitary (SPS) controls (U.S. Department of Agriculture 2008a; U.S. Department of Agriculture 2008b). The North American Free Trade Agreement (NAFTA) trading block is the
single largest supplier of fresh vegetables to the U.S. and accounts for 84 percent of U.S. vegetable imports (Huang and Huang 2007; U.S. Department of Agriculture 2007). The main sources of U.S. fresh fruit imports are the so-called “banana-exporting countries”, the southern hemisphere countries, and NAFTA partners. The banana exporting countries include Colombia, Costa Rica, Ecuador, Guatemala, Honduras and Panama, and these countries supply 36 percent of fresh fruit imports of which two-thirds are bananas (Huang and Huang 2007). Second to the banana-exporting countries in supplying U.S. fresh fruits are the Southern Hemisphere countries, which include Argentina, Australia, Brazil, Chile, New Zealand, South Africa, and Peru. Together the Southern Hemisphere countries supply 32 percent of U.S. fresh fruit imports. The third major source of U.S. fresh fruit imports is NAFTA, and it contributes approximately 27 percent of the total fresh fruit imports, mostly from Mexico (Huang and Huang 2007; U.S. Department of Agriculture 2007; Cook 2001).

The entry of more trading partners, such as the Dominican Republic-Central America Free Trade Agreement (CAFTA-DR) and the Chile-US Free Trade Agreement, further improved the availability of imports and encouraged more consumption of exotic fresh fruits and vegetables. Other supply factors that have encouraged imports include improved technology in shipping and storage, U.S. farm labor shortages and costs, and unfavorable U.S. continental climate (Lucier et al. 2006). As a result, the U.S. is increasingly dependent on importation of tropical produce to satisfy its demand, and it is currently a net importer of fresh produce.

The competitiveness of U.S. farm produce within the country and in the major U.S. fruit and vegetable export markets has been extensively studied (Andayani and Tilley 1997; Feleke 2006; Lee, Seale, and Jierwiriyapant 1990). However, few studies have investigated the U.S. demand for fresh fruit and vegetable imports. Given strong evidence of rapid growth in fresh
fruit and vegetable consumption and imports, it is important to understand the demand interrelationships and the seasonality effects that affect demand for these commodities.

This study analyzes import demand relationships among selected fresh tropical fruits and vegetables in the U.S. from 1989 to 2008. The purpose of the study is to estimate and provide reliable price elasticities of demand for U.S. fresh tropical fruit and vegetable imports and to identify any seasonality trends that affect the demand for imported fresh tropical fruits and vegetables. By assessing the demand relationships among fresh tropical fruit and vegetable imports in the U.S., the paper offers some policy recommendations for supplying countries’ strategies and U.S. trade policies for fresh fruits and vegetables.

3.2 Literature Review.

Common import demand analysis approaches involve the use of consumer demand theory and production theory. The consumer demand theory approach treats imports as final products that directly enter a consumer’s utility function (Schmitz and Seale 2002), while production theory treats imports as inputs (Washington and Kilmer 2002). The consumer demand theory approach enables the derivation of traditional consumer demand and labor supply functions from utility maximization. On the other hand, input demand and output supply functions from profit maximization or cost minimization can be obtained from production theory approaches.

Application of consumer approaches to import demand analysis is extensive. Empirical models include the Armington model (Armington 1969), AIDS model (Deaton and Muellbauer 1980) and Rotterdam model (Theil 1980). Past literature cautions against treating imports as final goods as in the past (Lee, Seale, and Jierwiriyapant 1990; Seale, Sparks, and Buxton 1992), because the nature of international trade is such that most goods are intermediate commodities
which require certain processing or repackaging before they are finally distributed to the
consumer (Washington and Kilmer 2002; Muhammad, Jones, and Hahn 2007). In such cases, a
production approach is better placed to estimate import demand. However, in the case of fresh
fruits and vegetables, imports are distributed to consumers in their fresh form and there is very
little value-added process involved. The imports can, therefore, be justifiably classified as final
goods and the AIDS model is deemed appropriate. Following Deaton and Muellbauer (1993,
1980), the Almost Ideal Demand System (AIDS) model can be expressed as follows:

\[ w_i = \alpha_i + \sum \gamma_{ij} \log p_j + \beta_i \log(y/P) + u_i \]  

(3.1)

where \( w_i \) is the expenditure share of good \( i \), \( y \) is total expenditure, and \( u_i \) denotes the disturbance
term. \( P \) is a price index defined as,

\[ \log p = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj} \log p_i p_j \]  

(3.2)

To be consistent with consumer demand theory, we must ensure that the demand system satisfies
adding-up, homogeneity in prices and income and Slutsky symmetry conditions hold as follows:

\[ \sum \alpha_k = 1, \quad \sum_k \gamma_{kj} = 0, \quad \text{and} \quad \sum \beta_k = 0 \quad \text{(adding-up property)} \]

\[ \sum_j \gamma_{kj} = 0 : \text{(homogeneity property)}, \quad \text{and} \]

\[ \gamma_{kj} = \gamma_{jk} : \text{(symmetry property)} \]

The intercept \( \alpha_i \) represents the estimated budget share of commodity \( i \) when all logarithmic
prices and real expenditures are zero and can be interpreted as the subsistence consumption of
commodity \( i \). The \( \beta_i \)'s are expenditure coefficients and represent the change in commodity \( i \)'s
expenditure share with respect to change in real income, \textit{ceteris paribus}. If \( \beta_i > 0 \), then that
commodity is a luxury, and if \( \beta_i < 0 \), the good is a necessity. Expenditure share \( w_i \) thus increases
with an increase in total expenditure if \( \beta_i > 0 \) and decrease if \( \beta_i < 0 \). The price coefficients, \( \gamma_{ij} \), represent the change in the \( i \)th budget share with respect to a percentage change in the \( j \)th price with real expenditures held constant. If \( \gamma_{ij} > 0 \), goods \( i \) and \( j \) are substitutes, whereas if \( \gamma_{ij} < 0 \), they are complementary goods.

To capture seasonality in the AIDS model, we apply seasonal trigonometric variables in each share equation following Arnade and Pick (1998) as follows:

\[
\begin{align*}
    w_i = \alpha_i + \sum \gamma_{ij} \log p_j + \beta_i \log(y/P) + n\alpha_iNafta + \sum_{u=1}^{4} \alpha_{iu} f_u + \sum_{v=1}^{4} \alpha_{iv} g_v + t\text{trend} + \epsilon_i
\end{align*}
\]

where \( f_u \) and \( g_u \) are seasonal functions defined as, 
\[
    f_u = \cos((u/z)\Pi t), \quad g_v = \sin((v/z)\Pi t).
\]

Here, \( t \) represents the observation number, while \( z = s/2 \) where \( s \) is the frequency of the data. Since we use quarterly data, \( s = 4 \) and \( z = 2 \). The variables \( u \) and \( v \) represent the seasonal frequencies of data, and the seasonal coefficients \( \alpha_{iu} \) and \( \alpha_{iv} \) measure the contribution of each seasonal cycle to the model (Arnade and Pick 1998).

The expenditure, own-price, and cross-price elasticities if demand can can be calculated at sample means as shown in equations (3.4), (3.55), and (3.6) respectively:

\[
\begin{align*}
    \eta_i &= 1 + (\beta_i / w_i) \\
    \varepsilon_{ii} &= 1 + (\gamma_{ii} / w_i) - \beta_i \\
    \varepsilon_{ij} &= (\gamma_{ij} / w_i) - \beta_i \left( w_j / w_i \right)
\end{align*}
\]

3.3 Data

The major fresh fruit and vegetable imports were selected for analysis based on consumption shares of imports and import growth. Fresh fruit imports, which happen to be
tropical fruits, were selected if their import consumption shares were greater 50 percent and the
top fresh vegetable imports were selected if the imports grew by over 50 percent. These
commodities were selection based on the top fresh fruit imports and data availability. For fresh
fruits commodities were selected if their import share of consumption is 50 percent or more.
Fresh vegetables with the highest import growth rate (over 50 percent) were selected subject to
data availability.

The fresh tropical fruits and vegetables considered in the study include bananas,
pineapples, avocados, papayas, and mangoes/guavas for tropical fresh fruits, and peppers,
tomatoes, cucumbers, and asparagus for fresh vegetables. Although mangoes and guavas are
different tropical fruits, FASonline reports data combined and so we define them as one
commodity, mangoes/guavas. The data set ranges from the 1st quarter of 1989 through the 3rd
quarter of 2008. Quarterly import quantities and values for the selected fresh fruits and
vegetables were calculated by aggregation of monthly quantities and values that were obtained
from the USDA’s Foreign Agricultural Statistics (FAS) website. Import values are measured on
a Cost, Insurance, and Freight (CIF) basis. Using import values and quantities, per-unit values
(cents/pound) for all the selected imports were calculated and used as proxies for import prices.
A summary of the descriptive statistics of the data are presented in Table 3.1.

Since most fresh fruit and vegetable imports portray one peak season per year (winter and
spring), we set $u$ and $v$ equal to 1. In addition we add a trend variable, $trend$, to capture any
trend in fresh tropical fruits and vegetable imports. We also introduce a dummy variable, $Nafta$,
to capture the effect of the implementation of the NAFTA trade agreement in 1995 between U.S.,
Canada, and Mexico. $Nafta$ equals 0 for the time period running from 1989 through 1994 and 1
thereafter.
Table 3.1. Quarterly Average Import Values, Quantities, Unit Values, and Expenditure Shares of U.S. Tropical Fresh Fruit and Vegetable Imports, 1989:1 – 2008:12.

<table>
<thead>
<tr>
<th>Tropical Fresh Fruit</th>
<th>Monthly Average</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantity (MT)</td>
<td>Unit Value (US¢/lb)</td>
<td>Value/Expenditures (US$ 1000)</td>
<td>Expenditure Share</td>
</tr>
<tr>
<td>Banana Imports</td>
<td>442141.71</td>
<td>16.07</td>
<td>7085910.68</td>
<td>0.4065</td>
</tr>
<tr>
<td>Pineapple Imports</td>
<td>34991.39</td>
<td>23.65</td>
<td>917595.48</td>
<td>0.0398</td>
</tr>
<tr>
<td>Papaya Imports</td>
<td>7145.26</td>
<td>30.53</td>
<td>226106.64</td>
<td>0.0097</td>
</tr>
<tr>
<td>Mango/Guava Imports</td>
<td>22025.88</td>
<td>44.05</td>
<td>813386.62</td>
<td>0.0400</td>
</tr>
<tr>
<td>Grapes Imports</td>
<td>49278.24</td>
<td>67.10</td>
<td>3349998.53</td>
<td>0.1313</td>
</tr>
<tr>
<td>Avocado Imports</td>
<td>10336.16</td>
<td>61.19</td>
<td>716224.96</td>
<td>0.0284</td>
</tr>
<tr>
<td>Tomato Imports</td>
<td>79763.06</td>
<td>45.65</td>
<td>3872769.98</td>
<td>0.1664</td>
</tr>
<tr>
<td>Pepper Imports</td>
<td>36314.01</td>
<td>62.75</td>
<td>2266096.07</td>
<td>0.0996</td>
</tr>
<tr>
<td>Cucumber Imports</td>
<td>36644.09</td>
<td>28.29</td>
<td>1084272.34</td>
<td>0.0460</td>
</tr>
<tr>
<td>Asparagus Imports</td>
<td>6988.99</td>
<td>95.24</td>
<td>744813.03</td>
<td>0.0324</td>
</tr>
</tbody>
</table>

3.4 Estimated Results

The AIDS demand model (3.3) is estimated for 10 fresh fruit and vegetable imports: bananas, pineapples, papaya, mangoes/guavas, grapes, avocados, tomatoes, peppers, cucumbers, and asparagus. Estimation employs TSP Version 5.0 (Hall and Cummins 2005) by iterated seemingly unrelated regression (ISUR) estimation. To conform to economic theory, homogeneity, symmetry, and adding-up conditions were imposed on the data. The equation for fresh grapes was dropped from the estimation process and its parameters are calculated from the estimated parameters. Results are presented in Tables 3.2, 3.3 and 3.4. Table 3.2 presents the estimated coefficients of the LA/AIDS model. Only three intercepts, $\alpha_i's$ for fresh papaya, fresh mango/guava, and fresh peppers are statistically significant. The real expenditure parameters (Table 3.2) for bananas, avocados, tomatoes, and asparagus are positive. While our expectations
are that imported fresh fruits and vegetables are luxuries, this finding for bananas and tomatoes is surprising, because they are considered more like staple commodities. Pineapples, papayas, mangoes, peppers, and cucumbers have \( \beta_i < 0 \), against our expectations.

The results show that NAFTA significantly impacted U.S. imports budget shares of fresh bananas, pineapples, papayas, avocados, tomatoes and peppers. NAFTA significantly increased fresh papayas, tomatoes and pepper import budget shares, as expected, due to improved availability. The entry of NAFTA resulted in the availability of a wide range of fresh fruits, which led to a shift of consumer expenditure from bananas which were previously the main fresh fruit imports to new commodities such as fresh papaya, mangoes/guavas, and peppers. This is inferred from the negative sign of NAFTA dummy for bananas and pineapples. The introduction of NAFTA resulted in a five percent reduction in the budget share for banana imports. Further, the bananas budget share equation has a negative, significant trend. This implies that budget shares for banana imports have been declining over the study period as consumers reallocate their budget towards other fresh fruit and vegetable imports. Import budget shares for pineapples, avocados, peppers, and cucumber have a positive trend, implying an increase in expenditure on imports in line with increased growth in their import values noted in the literature (Huang and Huang 2007). All the commodities have at least one seasonality variable that is statistically significant confirming that that seasonality plays a major role in the demand for tropical fresh fruits and vegetables.

The uncompensated elasticities of demand are calculated at sample means and shown in Table 3.3. The expenditure elasticities for imported fresh asparagus, tomatoes, avocados, and bananas are greater than one, implying that they are luxury goods. While the finding is justified
for imported fresh asparagus and avocados, because they are exotic commodities, the same may not be true for bananas and tomatoes, which are generally considered staple foods in the U.S.
Table 3.2: Estimates of LA/AIDS model of U.S. demand for tropical fresh fruits and vegetables with homogeneity and symmetry.

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<th>Fresh Bananas</th>
<th>Fresh Pineapple</th>
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<th>Fresh Grapes</th>
<th>Fresh Avocado</th>
<th>Fresh Tomatoes</th>
<th>Fresh Pepper</th>
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Numbers in parentheses are estimated standard errors. *, **, *** are significant at the 10 percent, 5 percent and 1 percent levels, respectively.
The own-price elasticities of demand for the fresh fruit and vegetable imports are positive, which conforms to economic theory that they are normal goods. The own-price elasticities of import demand range from -0.5416 for mangoes/guavas to -1.0995 for fresh tomatoes. Own-price elasticities of demand that are shown to be statistically significant are for bananas, mangoes/guavas, avocado, tomatoes, peppers, and cucumbers. The own-price elasticity for bananas is -0.5416, implying that a one percent increase in the price of bananas will result in a 0.54 percent reduction in budget share for imported bananas. The magnitude of the elasticity is comparable to -0.4236 and -0.4999 reported by You, Epperson and Huang (1996) and Huang (1993), respectively. Avocados have a price elasticity of -0.8823, which is near unity as expected.

The own-price elasticity for imported tomatoes is shown to be greater than unity, which is twice the -0.622 reported by Huang (1996) and -0.405 by You, Epperson and Huang (1996). Price elasticities for grapes and asparagus appear underestimated in comparison to You, Epperson and Huang (1996), while those of tomatoes, peppers, cucumbers appear much greater. The differences in our results are understandable since these comparison studies did not focus on imported commodities, were based on annual data while this studies uses monthly data, and were conducted long time ago. Others that appear to be unusually small include those for papaya and pineapples, despite the lack of comparative studies.

The estimated cross-price elasticities show that banana imports with papayas and asparagus imports are complements, since their cross-price elasticities are negative and significant. Pineapples and papayas, avocado, and asparagus are substitutes, owing to the positive cross-price elasticities. Grapes only have a relationship with papaya, which is a substitute. Mangoes/guavas are complements with papaya and avocados, possibly because of
fruit salad diets. However, the significant relationships between mangoes/guava and tomatoes and peppers goes against our expectations, although this could be due to combining mangoes, pepper, and tomatoes to make salsa.

As expected, tomatoes have a complementary relationship with cucumbers and peppers, as they are often cooked together or consumed in a combination as vegetable salads. Asparagus import is shown to be a significant complementary good with banana imports and substitute with fresh pineapples, mangoes/guavas, and papaya which is surprising because there are no known combinations of asparagus with bananas or substitution with any fruits.
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Numbers in parentheses are estimated standard errors. ***, **, and * are significant at the 1 percent, 5 percent and 10 percent levels, respectively. Statistically significant substitute and complementary goods are marked by red and blue colors respectively.

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<td>-.1880</td>
<td>.1531</td>
<td>.3474</td>
</tr>
<tr>
<td></td>
<td>(.3924)</td>
<td>(.1059)</td>
<td>(.0336)</td>
<td>(.1590)</td>
<td>(.3426)</td>
<td>(.0991)</td>
<td>(.1275)</td>
<td>(.1161)</td>
<td>(.1055)</td>
<td>(.1038)</td>
</tr>
<tr>
<td>Fresh Avocado</td>
<td>.1654</td>
<td>.2533**</td>
<td>.0110</td>
<td>-.2163</td>
<td>.5856</td>
<td>-.8499***</td>
<td>.2859</td>
<td>-.2806*</td>
<td>-.0308</td>
<td>.0763</td>
</tr>
<tr>
<td></td>
<td>(.4829)</td>
<td>(.1162)</td>
<td>(.0330)</td>
<td>(.1395)</td>
<td>(.3588)</td>
<td>(.2229)</td>
<td>(.2297)</td>
<td>(.1615)</td>
<td>(.1481)</td>
<td>(.1109)</td>
</tr>
<tr>
<td>Fresh Tomatoes</td>
<td>.6462***</td>
<td>-.0031</td>
<td>-.0050</td>
<td>.1274***</td>
<td>.0756</td>
<td>.0489</td>
<td>-.9194***</td>
<td>.0122</td>
<td>-.0437</td>
<td>.0610***</td>
</tr>
<tr>
<td></td>
<td>(.1302)</td>
<td>(.0235)</td>
<td>(.0066)</td>
<td>(.0307)</td>
<td>(.0733)</td>
<td>(.0393)</td>
<td>(.1131)</td>
<td>(.0364)</td>
<td>(.0333)</td>
<td>(.0227)</td>
</tr>
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<td>Fresh Pepper</td>
<td>.6202***</td>
<td>-.0095</td>
<td>.0194</td>
<td>-.0756</td>
<td>.1354</td>
<td>-.0801*</td>
<td>.0204</td>
<td>-.6774***</td>
<td>.0372</td>
<td>.0101</td>
</tr>
<tr>
<td></td>
<td>(.1572)</td>
<td>(.0410)</td>
<td>(.0127)</td>
<td>(.0467)</td>
<td>(.1271)</td>
<td>(.0461)</td>
<td>(.0609)</td>
<td>(.0696)</td>
<td>(.0456)</td>
<td>(.0389)</td>
</tr>
<tr>
<td>Fresh Cucumber</td>
<td>.1327</td>
<td>.0673</td>
<td>.0024</td>
<td>.1333</td>
<td>.2700</td>
<td>-.0190</td>
<td>-.1582</td>
<td>.0805</td>
<td>-.6005***</td>
<td>.0915</td>
</tr>
<tr>
<td></td>
<td>(.3123)</td>
<td>(.0803)</td>
<td>(.0241)</td>
<td>(.0918)</td>
<td>(.2516)</td>
<td>(.0916)</td>
<td>(.1204)</td>
<td>(.0988)</td>
<td>(.1275)</td>
<td>(.0759)</td>
</tr>
<tr>
<td>Fresh Asparagus</td>
<td>-.18394***</td>
<td>.3329*</td>
<td>.1741***</td>
<td>.4294***</td>
<td>-.35647***</td>
<td>.0670</td>
<td>.3135***</td>
<td>.0311</td>
<td>.1299</td>
<td>-.1237</td>
</tr>
<tr>
<td></td>
<td>(.4729)</td>
<td>(.1293)</td>
<td>(.0463)</td>
<td>(.1283)</td>
<td>(.4082)</td>
<td>(.0974)</td>
<td>(.1164)</td>
<td>(.1196)</td>
<td>(.1078)</td>
<td>(.1747)</td>
</tr>
</tbody>
</table>

Numbers in parentheses are estimated standard errors. ***, **, and * are significant at the 1 percent, 5 percent and 10 percent levels, respectively. Statistically significant substitute and complementary goods are marked by red and blue colors respectively.
3.5 Conclusions.

In this study, the LA/AIDS model was used to estimate the demand for U.S. tropical fresh fruit and vegetable imports, namely bananas, pineapples, papaya, mangoes/guavas, grapes, avocados, tomatoes, cucumbers, peppers, and asparagus. To capture seasonality and the effect of trade policy, we introduced trigonometric seasonality, trend, and a policy dummy variable. Results show that the NAFTA trade introduction significantly impacted expenditure shares for papayas, tomatoes and pepper positively, due to improved accessibility. However, it had a negative effect on budget shares for bananas and pineapples, as it resulted in entry of more varieties of fresh produce.

Most fresh fruit and vegetable import shares are shown to significantly and positively respond to real income/expenditures, implying that consumer income is a major factor in determining fresh fruit and vegetable imports into the U.S. Six out of the ten commodities show that own commodity prices are significant in deciding the imports.

Except for bananas, all the fresh fruits and vegetables show a positive trend in import budget shares. Trigonometric seasonality coefficients show the presence of seasonality in the budget shares for all the commodities. However, further modeling of the nature of seasonality is required to capture the phase and amplitude of the seasonality. A better approach would be to split the analysis into decades to alleviate the problem of the cycle phases overlapping over a long period due to entry of new trading partners and technological advancement. Another approach is to use an error correction model, which is explored in the next chapters.
CHAPTER 4
DYNAMIC ESTIMATION OF U.S. DEMAND FOR TROPICAL FRESH FRUIT IMPORTS

4.1 Introduction

Demand for fresh fruits has risen in the U.S. over the last three decades, due to a combination of several demand factors. The purchasing power of U.S. consumers rose over these years due to rising personal income, while research evidence in health, food, and nutrition also modified U.S. consumer perceptions and habits toward consuming more fresh fruits and vegetables. The heightened influx of an immigrant population accustomed to fresh-produce diets, mainly Asian and Hispanic populations, has also impacted the demand for fresh fruits.

Supply factors, such as the U.S. continental climate and a limited farm labor supply, on the other hand, have restricted the ability of U.S. producers to respond to the rising demand, making imports the more viable solution to satisfy the rising demand for fresh fruits (Huang and Huang 2007; Pollack 2001; Wells and Buzby 2008; Martin and Thompson 1992; Lucier et al. 2006). Free trade agreements, such NAFTA and CAFTA, and technological advances in shipping and handling of fresh produce, have also provided more access to fresh fruit imports over time. Thus, the importance of imports to U.S. fresh fruit consumption continues to grow.

According to USDA reports, between 1985 and 2005, the import share of U.S. fruit consumption rose from 2.3 percent to 15.5 percent for citrus and from 41.2 percent to 53 percent for non-citrus fruits (Huang and Huang 2007). The import share is even higher for U.S. tropical fruits consumption, largely due to climatic factors. The U.S. annual value of fresh fruits and
vegetable imports increased from real US$67 million to US$77.8 million from 1992 to 2006, of which tropical fresh fruits were the primary imports. The main fresh fruit imports comprise of bananas (44 percent), grapes, and other tropical fruits. These fruits largely originate from banana-exporting countries, the southern hemisphere, and Mexico (Huang and Huang 2007).

Despite these developments, few studies have examined demand for fresh fruits imports, particularly tropical fruits. Most of the available literature focuses on the competitiveness of U.S. farm fresh produce in general or in the domestic market (Cook 2001; Pollack 2001; You, Epperson, and Huang 1996) and on the main U.S. export markets for fresh produce (Andayani and Tilley 1997; Schmitz and Seale 2002; Yang and Koo 1994; Seale, Sparks, and Buxton 1992; Sparks 1992; Lee, Seale, and Jierwiriyapant 1990). Little reference has been made to the U.S. fresh fruit import market except for bananas and the import demand for fruit juices (Fonsah and Muhammad 2008).

This study contributes to the few existing studies by analyzing U.S. import demand for the top tropical fresh fruits, which also happen to comprise the bulk of U.S. fresh fruit imports. We estimate a dynamic version of the Almost Ideal Demand System (AIDS) model for U.S. imports of tropical fresh fruits by incorporating cointegration and an error correction concept. The top fresh tropical fruits selected for the study include bananas, pineapples, avocados, papayas, mangoes/guavas and grapes. For comparative coverage, all other fresh fruit imports and U.S fresh grapes are included in the estimated system. The objectives of the study are to estimate the long-run and short-run effects and elasticities of demand for the major tropical fresh fruits imported to the U.S.
4.2 Trends and Literature Review

Since the late 70’s, U.S. demand for fresh fruits and vegetables, and especially for tropical fruits, has been rapidly increasing, due to rising U.S. consumer incomes, increased awareness of the health benefits of consuming more fresh produce, and the impact of growing Asian and Hispanic populations in the U.S. who are accustomed to a culture of fresh produce in their meals. The ability to raise domestic production to meet the increased demand of tropical fresh fruits is impaired by an unfavorable climate and availability of farm labor, given the labor-intensive nature of fresh fruit production and harvest (Huang and Huang 2007; Martin and Thompson 1992; Cook 2001). Consequently, the U.S. is mainly dependent on imports to satisfy demand for tropical fresh fruits.

Although the demand for fresh fruit imports rose steadily over the last three decades, most of that growth was for tropical fresh fruits, mainly bananas, mangoes/ guavas, papaya, pineapples, avocados, and fresh grapes. The value of imports of pineapples, mangoes, guavas, papayas, and avocados was six times greater in 2006 compared to 1990, while the import value for grapes in 2006 grew by over 250 percent compared to 1990. Fresh bananas, which comprise the bulk of fresh fruit imports, showed no significant growth during that entire period (Huang and Huang 2007).

U.S. fresh fruit import supply is dominated by a few regions, perhaps due to high transport costs, the perishability of fresh fruits, and sanitary and phytosanitary (SPS) controls (U.S. Department of Agriculture 2008a; U.S. Department of Agriculture 2008b). The main sources of U.S. fresh fruit imports are the so-called “banana-exporting countries”, the southern hemisphere countries, and NAFTA partners. The banana-exporting countries include Colombia, Costa Rica, Ecuador, Guatemala, Honduras and Panama, which supply 36% of fresh fruit
imports, of which two-thirds are bananas (Huang and Huang 2007). Second to banana-exporting
countries in supplying U.S. fresh fruits are the Southern Hemisphere countries, which include
Argentina, Australia, Brazil, Chile, New Zealand, South Africa, and Peru. Together, Southern
Hemisphere countries supply 32% of U.S. fresh fruit imports. The third major source of U.S.
fresh fruit imports is NAFTA, which contributes approximately 27% of the total fresh fruit
imports, mostly from Mexico (Huang and Huang 2007; U.S. Department of Agriculture 2007;
Cook 2001).

The entry of more trading partners, such as the Dominican Republic-Central America
Free Trade Agreement (CAFTA-DR) and the Chile-U.S. Free Trade Agreement further
improved the availability of imports and encouraged more consumption of exotic fresh fruits.
Other supply factors that have encouraged imports include improved technology in shipping and
storage, U.S. farm labor shortages and costs, and an unfavorable U.S. continental climate (Lucier
et al. 2006). As a result, the U.S. increasingly depends on importation of tropical produce to
satisfy its demand.

4.3 Model Approach

Common import demand analysis approaches involve the use of consumer demand
theory and production theory. The consumer demand theory approach treats imports as final
products that directly enter a consumer’s utility function (Schmitz and Seale 2002), while
production theory treats imports as inputs (Washington and Kilmer 2002). The consumer
demand theory approach enables the derivation of traditional consumer demand and labor supply
functions from utility maximization. On the other hand, input demand and output supply
functions from profit maximization or cost minimization can be obtained from production theory
approaches.
Consumer approach applications to import demand analysis are extensive. Empirical models include the Armington model (Armington 1969), AIDS model (Deaton and Muellbauer 1980) and Rotterdam model (Theil 1980). Past literature cautions against treating imports as final goods as in the past (Lee, Seale, and Jierwiriyapant 1990; Seale, Sparks, and Buxton 1992), because the nature of international trade is such that most goods are intermediate commodities which require certain processing or repackaging before they are finally distributed to the consumer (Washington and Kilmer 2002; Muhammad, Jones, and Hahn 2007). In such cases, a production approach is better placed to estimate import demand. However, in the case of fresh fruits and vegetables, imports are distributed to consumers in their fresh form, and there is very little value-added processing involved. The imports can therefore be justifiably classified as final goods and the AIDS model is deemed appropriate.

Following Deaton and Muellbauer (1993, 1980), the Almost Ideal Demand System (AIDS) model can be expressed as follows:

$$w_i = \alpha_i + \sum \gamma_{ij} \log p_j + \beta_i \log(y/P) + u_i$$  \hspace{1cm} (4.1)

where $w_i$ is the expenditure share of good $i$, $y$ is total expenditure, $u_i$ denotes the disturbance term, and $P$ is a price index defined as,

$$\log p = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma^*_i j \log p_i p_j$$  \hspace{1cm} (4.2)

The intercept $\alpha_i$ represents the subsistence consumption of commodity $i$ and $\beta_i$ 's are expenditure coefficients that represent the change in commodity $i$ 's expenditure share with respect to change in real income, ceteris paribus. When $\beta_i > 0$, the respective commodity is a luxury, and if $\beta_i < 0$, the good is a necessity. This implies that expenditure share $w_i$ increases
with an increase in total expenditure if \( \beta_i > 0 \) and decreases if \( \beta_i < 0 \). The price coefficients, \( \gamma_{ij} \), represent the change in the \( i \)th budget share with respect to a percentage change in the \( j \)th price with real expenditures held constant. If \( \gamma_{ij} > 0 \), goods \( i \) and \( j \) are substitutes, whereas if \( \gamma_{ij} < 0 \), they are considered complementary goods.

To be consistent with consumer demand theory, we must ensure that the demand system satisfies adding-up, homogeneity in prices and income and Slutsky symmetry conditions hold as follows:

\[
\sum \alpha_k = 1, \quad \sum_{k} \gamma_{kj} = 0, \quad \text{and} \quad \sum_{k} \beta_k = 0 \quad \text{(adding-up property)}
\]

\[
\sum_{j} \gamma_{ijk} = 0 \quad \text{(homogeneity property), and}
\]

\[
\gamma_{ijk} = \gamma_{jki} \quad \text{(symmetry property)}
\]

When dealing with goods from different sources, we can further modify the AIDS model following Yang and Koo (1994) to formulate a source-differentiated specification of the AIDS model as,

\[
\ln \left( \frac{w_{ih}}{\alpha_{ih}} \right) = \sum_{j} \sum_{k} \gamma_{ihjk} \ln(p_{jk}) + \beta_{ih} \ln(E/P^*) \quad \text{(4.3)}
\]

\[
h = 1, 2, 3, ..., m \quad \text{and} \quad k = 1, 2, 3, ..., n
\]

where \( i \) and \( j \) represent commodities, and \( h \) and \( k \) indicate countries of origin for the goods. Commodity \( i \) may be imported from \( m \) different sources and \( j \) may be from \( n \) different sources. \( w_{ih} \) is the budget share of good \( i \) imported from source \( h \), and \( p_{jk} \) is the price of good \( j \) imported from source \( k \). The \( \alpha_i \) are the subsistence expenditure shares of goods \( i \), and \( \beta_i \) are the expenditure coefficients for commodities \( i \) expenditures. \( E \) denotes the total expenditure on all the goods in the demand system, while \( P^* \) is a price index defined as:
\[
\ln p^* = \alpha_0 + \sum_i \sum_h \alpha_i \ln(p_i^h) + \frac{1}{2} \sum_i \sum_h \sum_j \sum_k \gamma_{i,j,k}^* \ln(p_i^h) \ln(p_j^k)
\]  
(4.4)

As in the AIDS model, the index \( P^* \) is nonlinear, which makes the SDAIDS model nonlinear.

To mitigate the possible estimation difficulties associated with the nonlinear price index, we adopt the geometrically weighted average index, as suggested by Moschini (1995):

\[
\ln P = \sum_{ih} w_{ih}^0 \log(p_{ih})
\]  
(4.5).

The Marshallian elasticities of demand are then calculated, as in Andayani and Tilley (1997), using the following formulae:

\[
\varepsilon_{i,i} = 1 + \frac{\gamma_{i,k} - \beta_{i}}{w_{i}^k} \quad \text{(own-price elasticity)},
\]

\[
\varepsilon_{i,j} = \frac{\gamma_{i,k} - \beta_{i}}{w_{i}^k} \left( \frac{w_{j}^i}{w_{i}^k} \right) \quad \text{(cross-price elasticities of fresh product} \ i \ \text{among sources)},
\]

\[
\varepsilon_{i,j} = \frac{\gamma_{i,k} - \beta_{i}}{w_{i}^k} \left( \frac{w_{i}^j}{w_{i}^k} \right) \quad \text{(cross-price elasticity among fresh produce and sources)}, \quad \text{and}
\]

\[
\eta_{i} = 1 + \frac{\beta_{i}}{w_{i}^k} \quad \text{(expenditure elasticity)}.
\]

The AIDS model presented thus far assumes that consumption is always in equilibrium, which is not always true, especially with time series data. In reality, habit persistence, adjustment costs, imperfect information and incorrect expectations interfere with instant expenditure adjustment to prices and income changes. A recommended practice is to undertake stationarity and cointegration tests when working with time series data to determine if the data at hand are nonstationary and cointegrated. Nonstationarity in variables and the presence of cointegration in the equations would jeopardize the consistency of the parameters. In such cases, a dynamic...
version of the SDAIDS model is more suitable. We test for stationarity and cointegration in our
prices, expenditures shares and real expenditure using the Philips Perron test. We then modify
the AIDS model to an Error Correction Model version following Banerjee, Dolado, and Smith
(1986), Karagiannis, Katranidis, and Velentzas (2000) and Kremers, Ericsson, and Dolado
(1992) as follows,

\[
\Delta w_i = \delta_i \Delta w_{i,t-1} + \sum_j \sum_k \gamma_{ikj} \Delta \ln p_{jk} + \beta_i \Delta \ln (E / P^*) + \lambda_i u_{i,t-1}
\]  

(4.6)

where \( \Delta \) denotes the difference operator, \( u_{i,t-1} \) are the lagged estimated residual
from cointegration equations. The term \( \delta_i \) is the deviation of actual budget shares in the
previous period, \( w_{i,t-1} \). The ECM-SDAIDS is then estimated by iterated seemingly unrelated
regression (ISUR). Adding-up and symmetric conditions are expected to hold, just as in the
AIDS model.

4.4 Data

The selected U.S. tropical fresh fruit imports include bananas, pineapples, papayas,
mangoes/guavas, grapes, avocados, and all other U.S. fresh fruit imports. To capture the effects
of the U.S. fresh grapes, domestic fresh grapes supply is included in the analysis. Although to
some extent the U.S. supplies avocados and pineapples, mainly from California and Hawaii, they
are excluded in the analysis because the contribution is relatively small and the price data are
unavailable.

The data utilized in this study are monthly quantities and Cost, Insurance, and Freight
(CIF) import values from USDA’s Foreign Agricultural Service measured in metric tonnes and
thousand U.S. dollars, respectively. The data sample ranges from January 1989 through
December 2008. CIF import values are preferred to avoid the exclusion of shipping costs of tropical fresh fruits. Monthly per-unit values are calculated by dividing the monthly import values by quantities for all the selected tropical fresh imports and are used as proxies for import prices. For U.S. grapes, monthly shipments of fresh grapes are sourced from USDA’s Agricultural Marketing Service to serve as a proxy of the U.S. domestic quantities of fresh grapes. The prices of U.S. grapes are obtained from the Economic Research Service Fruits and Nuts Yearbooks.

Monthly expenditures are calculated from the quantities and prices, following which the total expenditure is derived by adding up all the individual fruit group expenditures. For each fresh fruit, expenditure shares are derived by dividing the total outlay by the individual fresh fruit expenditure. A dummy variable is also introduced to capture the effect of NAFTA trade policies since 1995, when NAFTA was enacted. A summary of the average monthly quantities, prices, expenditures, and budget shares are shown in Table 4.1.

**Table 4.1. Monthly Average Import Values, Quantities, Unit Values, and Expenditure Shares of U.S. Tropical Fresh Fruit Imports, 1989:1 – 2008:12.**

<table>
<thead>
<tr>
<th>Tropical Fresh Fruit</th>
<th>Quantity (MT)</th>
<th>Unit Value (US$/MT)</th>
<th>Value/Expenditures (US$ 1000)</th>
<th>Expenditure Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana Imports</td>
<td>328316.5</td>
<td>354.96</td>
<td>116326.00</td>
<td>0.3569</td>
</tr>
<tr>
<td>Pineapple Imports</td>
<td>26596.8</td>
<td>526.45</td>
<td>15537.20</td>
<td>0.0378</td>
</tr>
<tr>
<td>Papaya Imports</td>
<td>5404.8</td>
<td>675.05</td>
<td>3751.36</td>
<td>0.0094</td>
</tr>
<tr>
<td>Mango/Guava Imports</td>
<td>16396.1</td>
<td>1019.01</td>
<td>13424.90</td>
<td>0.0359</td>
</tr>
<tr>
<td>Grapes Imports</td>
<td>35975.9</td>
<td>1455.55</td>
<td>54094.30</td>
<td>0.1331</td>
</tr>
<tr>
<td>Avocado Imports</td>
<td>8183.8</td>
<td>1356.76</td>
<td>12593.70</td>
<td>0.0284</td>
</tr>
<tr>
<td>All Other Fruit Imports</td>
<td>131452.8</td>
<td>721.24</td>
<td>95638.50</td>
<td>0.2432</td>
</tr>
<tr>
<td>U.S. Grapes</td>
<td>53075.2</td>
<td>1185.03</td>
<td>116326.00</td>
<td>0.1554</td>
</tr>
</tbody>
</table>
4.5 Estimation Results

The Phillips-Perron unit and cointegration tests shown in Table 4.2 demonstrate that all the price series, real expenditures, and budget shares are nonstationary at the 10% significance level. Cointegration is present in all the fresh fruit expenditure share equations at the 10% significance level. All the unit root and cointegration statistic values are smaller than the critical values of -3.13 and -4.42, respectively, thus justifying the application of an error correction specification of the model.


<table>
<thead>
<tr>
<th>Fresh Fruit Variable</th>
<th>Label</th>
<th>Phillips Perron Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unit Root</td>
</tr>
<tr>
<td><strong>Budget Shares</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bananas</td>
<td>S1</td>
<td>-10.689</td>
</tr>
<tr>
<td>Pineapple</td>
<td>S2</td>
<td>-6.5119</td>
</tr>
<tr>
<td>Papaya</td>
<td>S3</td>
<td>-4.7768</td>
</tr>
<tr>
<td>Mango/Guavas</td>
<td>S4</td>
<td>-7.0149</td>
</tr>
<tr>
<td>Grapes</td>
<td>S5</td>
<td>-7.1414</td>
</tr>
<tr>
<td>Avocados</td>
<td>S6</td>
<td>-6.2447</td>
</tr>
<tr>
<td>Other Fruits</td>
<td>S7</td>
<td>-7.7598</td>
</tr>
<tr>
<td>U.S. Grapes</td>
<td>S8</td>
<td>-7.3276</td>
</tr>
<tr>
<td><strong>Log Prices</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bananas</td>
<td>LNP1</td>
<td>-4.4100</td>
</tr>
<tr>
<td>Pineapple</td>
<td>LNP2</td>
<td>-5.3567</td>
</tr>
<tr>
<td>Papaya</td>
<td>LNP3</td>
<td>-4.5395</td>
</tr>
<tr>
<td>Mango/Guavas</td>
<td>LNP4</td>
<td>-7.3855</td>
</tr>
<tr>
<td>Grapes</td>
<td>LNP5</td>
<td>-11.552</td>
</tr>
<tr>
<td>Avocados</td>
<td>LNP6</td>
<td>-7.0697</td>
</tr>
<tr>
<td>Other Fruits</td>
<td>LNP7</td>
<td>-8.7277</td>
</tr>
<tr>
<td>U.S. Grapes</td>
<td>LNP8</td>
<td>-9.9580</td>
</tr>
<tr>
<td>Real Expenditure (log)</td>
<td>LN E</td>
<td>-10.007</td>
</tr>
</tbody>
</table>

Critical values at 10% are -3.13 and -4.42 for unit root and cointegration tests, respectively.

Since cointegration tests are known to have a low power, we follow Banerjee, Dolado, and Smith (1986) and Kremers, Ericson and Dolado (1992) approach to test for cointegration.
The procedure involves the estimation of an ECM, followed by a test for the significance of the error correction term. If the null hypothesis is not rejected, then the series are not cointegrated. This step includes the estimation of the dynamic AIDS model using TSP 5.0 by iterated seemingly unrelated regression estimation. Adding-up, homogeneity and symmetry conditions are imposed to conform to demand theory. To avoid singularity problems, the equation for papaya expenditure shares is dropped from estimation and its parameters derived from economic theory restrictions.

Results of the ECM-AIDS model are presented in Table 4.3. As shown, the error correcting coefficient is negative and significant at the 1% level in all the expenditure share equations, which supports the Phillips-Perron tests for cointegration. Table 4.3 also presents the estimated coefficients of the ECM AIDS model. The estimated ECM expenditure parameters for grapes and other fresh fruit imports are positive, implying that these two fresh fruit groups are considered luxuries. While this finding is expected, we did not expect that mangoes/guavas, papaya, pineapples, and avocado would be shown to be negative because they are exotic and command a price premium. Bananas and U.S. fresh grapes have a negative expenditure coefficient implying that they are necessities. NAFTA trade agreement appears unimportant to U.S. tropical fresh fruit import expenditure shares, because tropical fruits originate mainly from banana-exporting countries and the Southern-Hemisphere countries.

<table>
<thead>
<tr>
<th></th>
<th>BANANA_{IM}</th>
<th>PINEAP_{IM}</th>
<th>PAPAYA_{IM}</th>
<th>MANGO /GUAVA_{IM}</th>
<th>GRAPES_{IM}</th>
<th>AVOCADO_{IM}</th>
<th>OTHER FRUITS_{IM}</th>
<th>GRAPES_{US}</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta s_{it-1} )</td>
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Below the estimated parameters, are the respective standard errors. ***, **, and * are significant at the 10 percent, 5 percent and 1 percent levels, respectively. IM=Imports. US=U.S. domestic supply.
The estimated elasticities of demand for the tropical fresh fruits analyzed are calculated at sample means. Uncompensated elasticities of demand are presented in Table 4.4, while the compensated demand and expenditure elasticities are shown in Table 4.5. However, we restrict our discussion to the compensated demand and expenditure elasticities in Table 4.5.

All the expenditure elasticities of demand are positive and significant at the 0.01 level, confirming that the expenditure shares are sensitive to changes in income. The expenditure elasticities for fresh grapes imports and other U.S. fresh fruit imports are greater than one (3.3193 and 1.2355 for fresh grapes imports and other fresh fruits imports, respectively), implying that they are luxury goods. Bananas are the most popular fruit in the U.S. and are consumed mainly as snacks. It is, therefore, not surprising that bananas’ expenditure elasticity is 0.2491. The expenditure elasticities for fresh pineapples and fresh papaya imports are 0.4179 and 0.4612, respectively, implying that these two exotic fresh fruits are also inelastic, contrary to our expectation that they would also be considered luxury goods. Avocado and U.S. fresh grapes expenditure elasticities are also less than unitary, 0.7998 and 0.7884, respectively.

The own-price elasticities of demand for all eight fresh fruit imports have the expected negative sign and are significant at the 0.01 and 0.05 levels, which confirm that they are normal goods based on economic theory. Own-price elasticities of demand range from -0.0952 for bananas to -1.3869 for mangoes/guavas. Fresh papaya and fresh mango/ guava import expenditure shares are shown to be price elastic, which is to be expected, given their exotic nature. The own-price elasticities of demand for papaya and mango/ guavas are -1.3211 and -1.3869, respectively, implying that the expenditure shares increase by about 1.32% and 1.39%, respectively, given a one percent decrease in the respective prices.
The magnitude of own-price elasticity of banana imports is -0.0952 and very small compared to -0.4236 reported by You, Epperson and Huang (1996), -0.4999 by Huang (1993). The difference in magnitude is likely due to the differences in time period of study, the use of monthly time period for changes in the demand specification of the ECM AIDS, and the fact that the previous studies focused on total consumption and not import demand as in our study. The price of fresh pineapple imports is also quite inelastic, at -0.3883, implying that if the price of fresh pineapple imports increase by 1%, the expenditure shares of fresh pineapples imports would decrease by only 0.39%. Similarly, the own-price elasticities of demand for other U.S. fresh fruit imports and U.S. fresh grapes are also inelastic within this time adjusting period at -0.4212 and -0.3758, respectively. This finding is counter to our expectations on the demand for exotic fresh fruits to be very sensitive to own-prices. Fresh grape imports and fresh avocado, on the other hand, are only slightly price inelastic at -0.6062 and -0.8524.

Table 4.5 also shows the results of the estimated cross-price elasticities of demand, which are important in determining the demand relationships of the various fresh fruit commodities. The estimated cross-price elasticities show that fruits that are complementary include bananas and fresh grapes imports, avocados and U.S. fresh grapes, and avocados and other fresh fruit imports. For these complementary fresh fruit commodities, the respective cross-price elasticities are negative and significant at the 10% levels or better.

Fresh avocado imports appear to be significant substitutes with bananas, papayas, mangoes/guavas, and imported fresh grapes, as their respective cross-price elasticities of demand are positive and significant. Although fresh grape imports are more intense during winter seasons when U.S. production is curtailed due to climate limitations, our results show that they also significantly compete with U.S. grapes supply. The cross-price elasticity of demand for fresh
grape imports and U.S. fresh grapes imply that the two are significant substitutes. Fresh grape import expenditures increase by 0.19% if the prices of U.S. grapes increase by one percent. This finding could be attributed to overlapping of grapes seasons over the years. Other significant fresh fruit substitutes include bananas and mangoes/guavas, papaya and pineapples, and fresh grapes imports and mangoes/guavas.
<table>
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<th>MANGO/GUAVA&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>GRAPES&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>AVOCADO&lt;sub&gt;IM&lt;/sub&gt;</th>
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Below the estimated elasticities, are the respective standard errors. ***, **, and * are significant at the 1 percent, 5 percent and 10 percent levels, respectively. Statistically significant substitute and complementary goods are marked by red and blue colors respectively. IM= Imports. US=U.S. domestic supply.

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Below the estimated elasticities, are the respective standard errors. ***, **, and * are significant at the 1 percent, 5 percent and 10 percent levels, respectively. Statistically significant substitute and complementary goods are marked by red and blue colors respectively. IM= Imports. US=U.S. domestic supply.
4.6 Conclusions

U.S. demand for tropical fresh fruits is analyzed using a dynamic AIDS model to determine demand relationships of the leading U.S. fresh fruit imports. The fresh fruits chosen for the study include fresh fruit imports of bananas, pineapples, papaya, mangoes/guavas, grapes, avocados, and other fresh fruit imports. Unit root and cointegration tests results show that all the series are nonstationary and cointegrated, hence justifying an error correction specification of the AIDS model.

The error correction results show that NAFTA does not importantly influence import behavior for tropical fresh fruit, perhaps due to the fact that, with an exception of mangoes, these commodities originate largely from non-NAFTA countries. All the fresh fruits expenditure shares are significant and positively respond to real income/expenditures, implying that consumer incomes are a major determinant of U.S. fresh fruit imports and that all the fresh fruits are normal goods. Fresh grape imports and other fresh fruit imports are found to be luxury commodities, while bananas are shown to be staples. Papayas and mangoes/guavas are price elastic, while bananas, pineapples, other fruit imports and U.S. grapes are price inelastic.

The findings from the study also show that fresh grape imports are significant substitutes to domestic grapes, suggesting that besides picking up supply during U.S. off-season production months, they also compete with U.S. domestically produced grapes during other seasons as well. Avocados are substitutes with bananas, papaya, mangoes/guavas, and grape imports. Bananas and mangoes/guavas, pineapples and papaya, and mangoes/guavas and grape imports are also substitutes. Complementary fresh fruits include bananas and grape imports, avocado and other fruit imports and U.S. grapes. Although some of the findings differ from expectations, the paper
provides elasticity estimates for U.S. fresh fruit imports for many topical fruits, such as mangoes, papaya, avocados and pineapples, which are unavailable in the existing literature.
CHAPTER 5
A DYNAMIC ESTIMATION OF U.S. DEMAND FOR A SELECT FRESH
VEGETABLE IMPORTS

5.1 Introduction

This chapter presents the estimation results of an ECM-AIDS model of demand for the fastest growing fresh vegetable imports in the U.S. The fresh vegetables selected for the analysis are tomatoes, cucumbers, peppers, asparagus and all other U.S. fresh vegetable imports. The sources of fresh vegetables are grouped into U.S. imports and U.S. domestic supply for the chosen fresh vegetables. The objective is to determine the competitiveness of the major fresh vegetable imports and to estimate the static AIDS and the ECM-AIDS elasticities of demand for these fresh vegetables.

The remainder of the paper is organized as follows. A brief review of the literature on estimation approaches is presented in the next section, followed by a detailed description of the data and the quantitative techniques used in this analysis. This is followed by a presentation of the results of the analysis and, finally, the conclusions and implications drawn from the study.

5.2 Model Specification

We estimate both static and Error Correction Model versions of the Almost Ideal Demand Systems model following Banerjee, Dolado, and Smith (1986), Karagiannis, Katranidis, and Velentzas (2000) and Kremers, Ericsson, and Dolado (1992) as follows,

\[ \Delta w_{ij} = \delta_i \Delta w_{ij-1} + \sum_j \sum_k \nu_{ijk} \Delta \ln p_{ij} + \beta_i \Delta \ln (E/P^*) + \lambda_i u_{ij-1} \]  

(6.1)
where $i_k$ represents fresh vegetable $i$ from source $k$. The $\Delta$ denotes the difference operator, and $u_{\Delta t-1}$ are the lagged estimated residuals from the cointegration equations for $i$. The term $\delta_{kt}$ is the deviation of actual budget shares in the previous period, $w_{kt-1}$. The ECM-SDAIDS is then estimated by iterated seemingly unrelated regression (ISUR). Adding-up and symmetric conditions are expected to hold, just as in the AIDS model.

5.3 Data Description

The data utilized for this study include monthly import quantities (metric tons) and import values (CIF) for select fresh vegetables that include tomatoes, cucumbers, peppers, asparagus, and all other fresh vegetable imports. The data are sourced from USDA’s Foreign Agricultural Statistics from January 1989 to December 2008. The data show that, other than the U.S. domestic supply, NAFTA (in particular Mexico) is the sole supplier of these fresh vegetables; that is, 97 percent, 89 percent, and 98 percent for tomatoes, peppers and cucumbers, respectively. In fact, Mexico’s contribution is more than 70 percent for each commodity. This limits the extent to which the sources can be differentiated. We therefore differentiate fresh vegetable sources into two sources: imports (mainly NAFTA) and U.S. domestic supply.

The import values for each fresh vegetable group represent the commodities’ import expenditures. Unit values of the imports are used as proxies for import prices and are measured by dividing the reported import values by the reported imported quantities. U.S. monthly consumption data for locally produced fresh vegetables is not readily available. To circumvent this limitation, we use monthly fresh vegetable shipments from USDA’s Agricultural Marketing Service as proxies for U.S. domestic fresh vegetable supply. U.S. prices for tomatoes, peppers,
cucumbers, and asparagus are obtained from Vegetables and Melon Yearbooks. For each fresh vegetable and source, monthly expenditures are calculated from the quantities and prices, following which total expenditure and fresh vegetable expenditure shares are derived. In the event that some U.S. domestic prices are missing, the world prices for the fresh vegetable are used. However, we note that using monthly shipments of fresh vegetables might introduce a bias, because these shipments do not capture all the produce consumed and, in some cases, they include produce destined for the export market. We also included a dummy variable to capture the impact of NAFTA trade agreement by defining Nafta equal 0 for the time period running from 1989 through 1994 and 1 thereafter since NAFTA was implemented in 1995.


<table>
<thead>
<tr>
<th>Tropical Fresh Vegetable Imports</th>
<th>Quantity (MT)</th>
<th>Unit Value (US$/MT)</th>
<th>Value/Expenditures (US$ 1000)</th>
<th>Expenditure Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>59292.46</td>
<td>1013.46</td>
<td>63741.5</td>
<td>0.1094</td>
</tr>
<tr>
<td>Pepper</td>
<td>27331.60</td>
<td>1413.71</td>
<td>37413.8</td>
<td>0.0637</td>
</tr>
<tr>
<td>Cucumber</td>
<td>27271.82</td>
<td>632.96</td>
<td>17869</td>
<td>0.0300</td>
</tr>
<tr>
<td>Asparagus</td>
<td>5324.34</td>
<td>2179.46</td>
<td>12593.9</td>
<td>0.0214</td>
</tr>
<tr>
<td>Other Veggies</td>
<td>105243.51</td>
<td>592.48</td>
<td>65375.8</td>
<td>0.1159</td>
</tr>
<tr>
<td>US Tomato</td>
<td>52917.54</td>
<td>1185.03</td>
<td>52114.8</td>
<td>0.4943</td>
</tr>
<tr>
<td>US Peppers</td>
<td>91525.71</td>
<td>2872.22</td>
<td>25710.5</td>
<td>0.1253</td>
</tr>
<tr>
<td>US Cucumber</td>
<td>27352.27</td>
<td>2575.76</td>
<td>71691.4</td>
<td>0.0202</td>
</tr>
<tr>
<td>US Asparagus</td>
<td>19556.02</td>
<td>506.62</td>
<td>969150.1</td>
<td>0.0199</td>
</tr>
</tbody>
</table>

The top fresh vegetable imports were selected for analysis based whether their import value growth were greater than 50 percent and also on data availability particularly monthly
price data for U.S. domestically produced fresh vegetables. In total, we constituted nine (9) fresh vegetable equations: tomatoes imports, peppers imports, cucumbers imports, asparagus imports, all other fresh vegetables imports, US tomatoes, US peppers, US cucumbers, and US asparagus. The descriptive statistics of the budget shares utilized in this analysis are presented in Table 5.1. Because we used monthly data, we conducted Philips-Perron tests for stationarity and cointegration in all the series and equations. Results are presented in Table 5.2, which confirm nonstationarity and the presence of cointegration in the data, justifying an Error Correction version estimation of the AIDS model.

Table 5.2. Unit root and Cointegration tests, U.S. fresh vegetable imports, 1989-2008.

<table>
<thead>
<tr>
<th>Fresh Vegetable Variable</th>
<th>Label</th>
<th>Unit Root Test</th>
<th>Cointegration Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Budget Shares</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>S1</td>
<td>-7.5527</td>
<td>-7.6383</td>
</tr>
<tr>
<td>Pepper</td>
<td>S2</td>
<td>-7.8356</td>
<td>-8.4457</td>
</tr>
<tr>
<td>Cucumber</td>
<td>S3</td>
<td>-6.6846</td>
<td>-7.325</td>
</tr>
<tr>
<td>Asparagus</td>
<td>S4</td>
<td>-7.8676</td>
<td>-8.1438</td>
</tr>
<tr>
<td>Other Veggies</td>
<td>S5</td>
<td>-6.5903</td>
<td>-7.1294</td>
</tr>
<tr>
<td>US Tomato</td>
<td>S6</td>
<td>-6.8856</td>
<td>-7.7257</td>
</tr>
<tr>
<td>US Peppers</td>
<td>S7</td>
<td>-6.8384</td>
<td>-8.0945</td>
</tr>
<tr>
<td>US Cucumber</td>
<td>S8</td>
<td>-7.8513</td>
<td>-9.1785</td>
</tr>
<tr>
<td>US Asparagus</td>
<td>S9</td>
<td>-6.8432</td>
<td>-7.7741</td>
</tr>
<tr>
<td><strong>Log prices/Expenditure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomato</td>
<td>LNP1</td>
<td>-7.5527</td>
<td></td>
</tr>
<tr>
<td>Pepper</td>
<td>LNP2</td>
<td>-15.682</td>
<td></td>
</tr>
<tr>
<td>Cucumber</td>
<td>LNP3</td>
<td>-6.5258</td>
<td></td>
</tr>
<tr>
<td>Asparagus</td>
<td>LNP4</td>
<td>-10.564</td>
<td></td>
</tr>
<tr>
<td>Other Veggies</td>
<td>LNP5</td>
<td>-9.8732</td>
<td></td>
</tr>
<tr>
<td>US Tomato</td>
<td>LNP6</td>
<td>-5.7621</td>
<td></td>
</tr>
<tr>
<td>US Peppers</td>
<td>LNP7</td>
<td>-4.6266</td>
<td></td>
</tr>
<tr>
<td>US Cucumber</td>
<td>LNP8</td>
<td>-10.132</td>
<td></td>
</tr>
<tr>
<td>US Asparagus</td>
<td>LNP9</td>
<td>-9.0932</td>
<td></td>
</tr>
<tr>
<td>Real Expenditure</td>
<td>LN E</td>
<td>-10.19</td>
<td></td>
</tr>
</tbody>
</table>

Critical Values at 10% are -3.13 and -4.42 for unit root and cointegration tests, respectively.
5.4 ECM-AIDS Results

We follow Banerjee, Dolado, and Smith (1986) and Kremers, Ericson and Dolado (1992) for their suggested methods of testing for cointegration. They suggest formulating and estimating an ECM, and then testing for the significance of the error correction term. If the null hypothesis that the coefficient of the error correcting term is not significantly different from zero is not rejected, then the series is not cointegrated (Karagiannis and Mergos 2002). But, if the null hypothesis is rejected, then the series is cointegrated. This approach confirms that the series are cointegrated, as seen in Table 5.3. Notably, the error correcting coefficient is negative and statistically significant at the 1 percent significance level in all the expenditure share equations which meets our expectations.

However, the finding that the NAFTA trade block has no significant role in fresh vegetable expenditure is unexpected. An explanation for this finding may be that U.S. fresh vegetable supply is either solely from domestic production or imports from Mexico, and so factoring in the trade block does not mean anything, since the U.S. fresh vegetable market is not open to other regions.

<table>
<thead>
<tr>
<th></th>
<th>TOMATO&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>PEPPER&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>CUCUM&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>ASPARA&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>OTHER&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>TOMATO&lt;sub&gt;US&lt;/sub&gt;</th>
<th>PEPPER&lt;sub&gt;US&lt;/sub&gt;</th>
<th>CUCUM&lt;sub&gt;US&lt;/sub&gt;</th>
<th>ASPAR&lt;sub&gt;US&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δs&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.1596***</td>
<td>0.1392***</td>
<td>-1.5427***</td>
<td>0.3564***</td>
<td>0.1332***</td>
<td>0.1629***</td>
<td>0.1036***</td>
<td>0.2678***</td>
<td>0.2199***</td>
</tr>
<tr>
<td>Δs&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.0242</td>
<td>0.0327</td>
<td>0.1480</td>
<td>0.0402</td>
<td>0.0265</td>
<td>0.0212</td>
<td>0.0220</td>
<td>0.0423</td>
<td>0.0334</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.0393***</td>
<td>0.0196***</td>
<td>0.0029</td>
<td>0.0024</td>
<td>0.0029</td>
<td>0.0024</td>
<td>0.0024</td>
<td>0.0024</td>
<td>0.0024</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;2&lt;/sub&gt;</td>
<td>-0.0127***</td>
<td>0.0196***</td>
<td>0.0029</td>
<td>0.0024</td>
<td>0.0029</td>
<td>0.0024</td>
<td>0.0024</td>
<td>0.0024</td>
<td>0.0024</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;3&lt;/sub&gt;</td>
<td>-0.0060***</td>
<td>-0.0048***</td>
<td>0.0028</td>
<td>0.0022</td>
<td>0.0028</td>
<td>0.0022</td>
<td>0.0022</td>
<td>0.0022</td>
<td>0.0022</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;4&lt;/sub&gt;</td>
<td>-0.0117***</td>
<td>-0.0016***</td>
<td>0.0003</td>
<td>0.0002</td>
<td>0.0003</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.0002</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;5&lt;/sub&gt;</td>
<td>-0.0283***</td>
<td>-0.0002***</td>
<td>0.0047</td>
<td>0.0028</td>
<td>0.0047</td>
<td>0.0028</td>
<td>0.0028</td>
<td>0.0028</td>
<td>0.0028</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;6&lt;/sub&gt;</td>
<td>0.0332***</td>
<td>-0.0003***</td>
<td>0.0108</td>
<td>0.0049</td>
<td>0.0108</td>
<td>0.0049</td>
<td>0.0049</td>
<td>0.0049</td>
<td>0.0049</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;7&lt;/sub&gt;</td>
<td>0.0067</td>
<td>-0.0016***</td>
<td>0.0060</td>
<td>0.0031</td>
<td>0.0060</td>
<td>0.0031</td>
<td>0.0031</td>
<td>0.0031</td>
<td>0.0031</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;8&lt;/sub&gt;</td>
<td>-0.0072***</td>
<td>-0.0001***</td>
<td>0.0023</td>
<td>0.0014</td>
<td>0.0023</td>
<td>0.0014</td>
<td>0.0014</td>
<td>0.0014</td>
<td>0.0014</td>
</tr>
<tr>
<td>Δln p&lt;sub&gt;9&lt;/sub&gt;</td>
<td>0.0002</td>
<td>0.0017</td>
<td>-0.0065***</td>
<td>0.0021</td>
<td>0.0002</td>
<td>0.0017</td>
<td>0.0017</td>
<td>0.0017</td>
<td>0.0017</td>
</tr>
<tr>
<td>Δln E</td>
<td>-0.0972***</td>
<td>-0.0465***</td>
<td>0.0038</td>
<td>0.0021</td>
<td>0.0038</td>
<td>0.0021</td>
<td>0.0021</td>
<td>0.0021</td>
<td>0.0021</td>
</tr>
<tr>
<td>u&lt;sub&gt;1&lt;/sub&gt;-1</td>
<td>-0.5122***</td>
<td>-0.5556***</td>
<td>0.0002</td>
<td>0.0040</td>
<td>0.0002</td>
<td>0.0040</td>
<td>0.0040</td>
<td>0.0040</td>
<td>0.0040</td>
</tr>
<tr>
<td>R-Sq.</td>
<td>0.5252</td>
<td>0.4702</td>
<td>0.5653</td>
<td>0.4743</td>
<td>0.5061</td>
<td>0.5218</td>
<td>0.4283</td>
<td>0.2126</td>
<td></td>
</tr>
<tr>
<td>D-W</td>
<td>1.6896</td>
<td>1.3430</td>
<td>1.7374</td>
<td>1.3551</td>
<td>1.4090</td>
<td>1.7428</td>
<td>1.8802</td>
<td>1.4657</td>
<td></td>
</tr>
<tr>
<td>LogL</td>
<td>5366.35</td>
<td>3665.35</td>
<td>5366.35</td>
<td>3665.35</td>
<td>5366.35</td>
<td>3665.35</td>
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<tr>
<td>N</td>
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<td>238</td>
<td>238</td>
<td>238</td>
<td>238</td>
<td>238</td>
<td>238</td>
<td></td>
</tr>
</tbody>
</table>

Below the estimated parameters, are the respective standard errors. ***, **, and * are significant at the 1 percent, 5 percent and 10 percent levels, respectively. IM= Imports. US=U.S. domestic supply.
The uncompensated and compensated elasticities of demand are calculated at sample means and shown in Tables 5.4 and 5.5, respectively. The expenditure and own-price elasticities of demand are shown in bold. The uncompensated elasticity estimates are slightly larger and very close to the compensated elasticities. However, we focus our discussion on the compensated elasticity estimates. The expenditure elasticities of demand for all the fresh vegetables are positive and statistically significant, with the exception of tomato imports (Table 5.4). U.S. asparagus and tomatoes are shown to be luxury fresh vegetables, because the expenditure elasticities are greater than one. This finding is consistent with recent literature that tomatoes have been fetching high prices as result of production interruptions due to adverse weather such as hurricanes in the southeast coast (Fonsah 2006b; Huang 2004; Huang and Huang 2007). The rest of fresh vegetables are considered necessities, as their elasticities are less than one. However, demand for all the analyzed fresh vegetables significantly respond to changes in expenditures.

The compensated own-price elasticities shown in Table 5.5 are negative and significant, except for U.S. peppers. The own-price elasticity for imported fresh cucumbers is -1.0987 and slightly more than unitary, and that of imported asparagus is -0.9003. Own-price elasticities for tomatoes, peppers, and all the other imports are -0.5317, -0.6284, and -0.5197, respectively. It is evident that fresh imports are more price-elastic compared to U.S. fresh domestic vegetables. For instance, the own-price elasticity of demand for U.S. asparagus is -0.7084 compared to -0.9003 for imports. U.S. fresh cucumbers, on the other hand, are price inelastic (-0.2366) compared to -1.0987 for imports. Imported tomatoes also have a higher own-price elasticity of -0.5317 compared to -0.4505 for U.S. supplied tomatoes. Except for U.S. peppers, the results for own price elasticities are comparable to You, Epperson, and Huang (1996) study in which they
obtained -0.405, -0.5762, -0.2976, and -0.2472 for tomatoes, asparagus, cucumbers and peppers, respectively. Once more, it is quite clear that demand for the selected fresh vegetables respond significantly to the respective own price.
### Table 5.4. Expenditure and Uncompensated Elasticities for LA/AIDS for U.S. fresh vegetable imports and domestic supply, 1989–2008.

<table>
<thead>
<tr>
<th></th>
<th>TOMATO&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>PEPPER&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>CUCUM&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>ASPARA&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>OTHER&lt;sub&gt;IM&lt;/sub&gt;</th>
<th>TOMATO&lt;sub&gt;US&lt;/sub&gt;</th>
<th>PEPPER&lt;sub&gt;US&lt;/sub&gt;</th>
<th>CUCUM&lt;sub&gt;US&lt;/sub&gt;</th>
<th>ASPAR&lt;sub&gt;US&lt;/sub&gt;</th>
<th>REAL Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>** **</td>
<td>-0.5438***</td>
<td>-0.0600**</td>
<td>-0.0285</td>
<td>-0.0879***</td>
<td>-0.1553***</td>
<td>0.7428***</td>
<td>0.0498</td>
<td>-0.0477**</td>
<td>0.0194</td>
<td>0.1111</td>
</tr>
<tr>
<td><strong>0.0670</strong></td>
<td>0.0266</td>
<td>0.0257</td>
<td>0.0164</td>
<td>0.0435</td>
<td>0.1184</td>
<td>0.0578</td>
<td>0.0211</td>
<td>0.0349</td>
<td>0.1022</td>
<td></td>
</tr>
<tr>
<td>PEPPER&lt;sub&gt;IM&lt;/sub&gt;</td>
<td>-0.1203***</td>
<td>-0.6455***</td>
<td>-0.0538</td>
<td>-0.0092</td>
<td>0.0812*</td>
<td>0.3565***</td>
<td>0.0671</td>
<td>0.0133</td>
<td>0.0415</td>
<td>0.2692***</td>
</tr>
<tr>
<td><strong>0.0452</strong></td>
<td>0.0371</td>
<td>0.0348</td>
<td>0.0197</td>
<td>0.0444</td>
<td>0.0893</td>
<td>0.0503</td>
<td>0.0223</td>
<td>0.0325</td>
<td>0.0762</td>
<td></td>
</tr>
<tr>
<td>CUCUM&lt;sub&gt;IM&lt;/sub&gt;</td>
<td>-0.1322</td>
<td>-0.1203</td>
<td><strong>-1.1100</strong>*</td>
<td>0.1364***</td>
<td>0.2212</td>
<td>0.5393***</td>
<td>-0.0150</td>
<td>0.2140***</td>
<td><strong>-0.1082</strong></td>
<td>0.3749***</td>
</tr>
<tr>
<td><strong>0.0913</strong></td>
<td>0.0727</td>
<td>0.2178</td>
<td>0.0625</td>
<td>0.1524</td>
<td>0.1645</td>
<td>0.0932</td>
<td>0.0595</td>
<td>0.0718</td>
<td>0.1315</td>
<td></td>
</tr>
<tr>
<td>ASPARA&lt;sub&gt;IM&lt;/sub&gt;</td>
<td>-0.4588***</td>
<td>-0.0221</td>
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Below the estimated elasticities, are the respective standard errors. ***, ***, and * are significant at the 1 percent, 5 percent and 10 percent levels, respectively. Statistically significant substitute and complementary goods are marked by red and blue colors respectively. IM= Imports. US=U.S. domestic supply.

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Below the estimated elasticities, are the respective standard errors. ***, **, and * are significant at the 1 percent, 5 percent and 10 percent levels, respectively. Statistically significant substitute and complementary goods are marked by red and blue colors respectively. IM= Imports. US=U.S. domestic supply.
The estimated cross-price elasticities of demand show expected relationships between the import demand for fresh vegetables. Based on the negative sign and significant cross-price elasticity of demand, tomato imports are shown to be complementary goods with fresh peppers imports, asparagus imports, all other fresh vegetable imports, and U.S. cucumbers. These findings appear to confirm the common consumption habits for tomatoes, which are widely combined and consumed with a wide range of other fresh vegetables. Other apparently complementary fresh vegetables include U.S. asparagus and all the other fresh vegetables imports.

Results also show that fresh vegetable imports are substitutes for U.S. supplied fresh vegetables with the exception of asparagus. The cross-price elasticities of demand are positive and significant for domestically supplied fresh tomatoes and fresh tomato imports, fresh pepper imports and U.S. peppers, and fresh cucumber imports and U.S. cucumbers. This finding is consistent with the widely documented tomato and bell pepper wars between Florida and Mexico and lately Canadian greenhouse tomatoes cited in the literature even before NAFTA’s initiation (Estes 2003; VanSickle 1996, 2002; VanSickle, Evans, and Emerson 2003). Since almost all the imports originate from Mexico and the rest from Canada, which have common climate and season with the U.S, these imports are actually competing with U.S. fresh vegetables all the year round. Other fresh vegetables that are significant substitutes include U.S. tomatoes and fresh pepper imports, asparagus imports, cucumber imports, and all other fresh vegetable imports. Asparagus and cucumber imports are also substitute goods, as are all the other fresh vegetable imports and pepper imports and asparagus imports.
5.5. **Conclusions**

This chapter estimates a dynamic version of a source-differentiated AIDS model for selected fresh vegetables that include fresh tomatoes, peppers, cucumbers, and asparagus. The sources for these fresh vegetables are categorized into U.S. domestic source and total imports. Unit root and cointegration tests reveal that all the series are nonstationary and cointegrated. An Error-Correction version of the Aids model is thus estimated, and results show that most fresh vegetable imports are more price elastic compared to domestic vegetables. Cucumbers and asparagus are found to be price elastic. Also, expenditure shares for all the fresh vegetables are responsive to changes in real expenditure and increases with an increase in expenditure.

Findings from the study also imply that most fresh vegetable imports into the U.S. significantly compete with domestic fresh vegetables, as is shown by the finding that all fresh vegetable imports are significant substitutes with U.S. vegetables, such as the case of tomatoes, peppers, and cucumbers. However, asparagus does not show any relationship between imports and local produce. We observe that the use of fresh vegetable shipments as a proxy for U.S. quantities is likely to introduce bias to our estimates and this might be the reason our expenditure elasticities for U.S. vegetables are higher than those of imports. However, the study offers the industry some insights into the demand relationships of fresh vegetable imports and U.S. domestically produced fresh produce.
CHAPTER 6
A SOURCE-DIFFERENTIATED ANALYSIS OF TROPICAL FRESH FRUIT IMPORTS

6.1 Introduction

Chapter 6 presents the empirical results of a source-differentiated AIDs model of tropical fresh fruits. The tropical fresh fruits chosen for analysis include fresh bananas, fresh pineapples, papayas, mangoes/guavas, grapes, and avocados. The top countries of origin for each tropical fresh fruit are selected for analysis. The main objective of this analysis is to determine U.S. import demand relationships between tropical fresh fruits from different countries. The rest of the chapter is organized as follows: A brief literature review is presented in section 6.2, followed by the empirical model and data description. The estimation results are presented in section 6.5 followed by conclusions and implications.

6.2 Model Approach

Both the Armington trade model and the AIDS model are commonly used in the literature to analyze source-differentiated import demands. However, the Armington model is criticized due to its assumptions of constant elasticity of substitution and homotheticity (Henneberry and Hwang 2007). In contrast, the AIDS model represents a flexible, complete demand system and does not require the additivity of utility function. The AIDS model satisfies the axioms of choice and aggregates perfectly under certain conditions over consumers, giving it many advantages over the Armington model.
Because the main objective of this chapter is to analyze the competitiveness of sources of U.S. tropical fresh fruits, a source-differentiated AIDS (SDAIDS) model is preferred. The SDAIDS model was proposed by Yang and Koo (1994). The model closely follows the derivation of the AIDS model by Deaton and Muellbauer (1980) and has been used in import demand studies (Boonsaeng 2006; Henneberry and Hwang 2007; Yang and Koo 1994; Boonsaeng, Fletcher, and Carpio 2008). The SDAIDS allows for source differentiation of various tropical fresh fruits without imposing block separability. Its main advantage is that it does not suffer from aggregation bias over import sources or over products.

The SDAIDS employed follows Henneberry and Hwang (2007) and Yang and Koo (1994) as

\[ w_{ih} = \alpha_{ih} + \sum_j \sum_k \gamma_{ih,k} \ln(p_{jk}) + \beta_{ih} \ln(E/P^*) \]  \hspace{1cm} (6.1)

where, \( h = 1, 2, 3, ..., m \) and \( k = 1, 2, 3, ..., n \)

where, \( i \) and \( j \) represent commodities, and \( h \) and \( k \) indicate countries of origin for the goods. Commodity \( i \) may be imported from \( m \) different sources and \( j \) may be from \( n \) different sources. \( w_{ih} \) is the budget share of good \( i \) imported from source \( h \) and \( p_{jk} \) is the price of good \( j \) imported from source \( k \). The term \( E \) denotes the total expenditure on all the goods in the demand system, while \( P^* \) is a price index defined as

\[ \ln P^* = \alpha_0 + \sum_i \sum_h \alpha_i \ln(p_{ih}) + \frac{1}{2} \sum_i \sum_h \sum_j \sum_k \gamma_{ih,k} \ln(p_{ih}) \ln(p_{jk}) \]  \hspace{1cm} (6.2)

The index \( P^* \) is nonlinear, making the SDAIDS model nonlinear, also. Several alternative forms can be used to transform the system to a linear approximation. These include a regular price index proposed by Moschini (1994), the Tornquist index, the “corrected” Stone index, and the geometrically weighted average of prices (Moschini 1994, 1995; Moschini and
Meilke 1989). The geometrically weighted average of prices is chosen as the alternative price index here. The geometric weighted average price index is expressed as

$$\log \left( P_i^c \right) = \sum_{i=1}^{n} w_i^0 \log \left( p_i \right). \quad (6.3)$$

This geometrically weighted index is an analogue of the Laspeyres price index and does not change with changes in units of measurement up to a multiplicative constant, allowing further simplification necessary for an approximating index.

The SDAIDS involves large number of estimated parameters, due to the number of sources per each commodity, and thus creates a degrees of freedom problem. This problem is addressed by imposing restrictions on the parameters, as in Yang and Koo (1994), so that

$$\gamma_{i,k} = \gamma_{i,j} \quad \forall k \neq j$$

which implies that the cross-price effects are not source differentiated between products but are differentiated within a product. For instance, U.S. demand for Mexican mangoes have no source differentiated cross-price effects with demand for Chilean pineapples and other countries, but they do have source-differentiated cross-price effects with demand for mangoes from Chile or other countries. The assumption results to the following restricted SDAIDS (RSADAIDS) model:

$$w_i = \alpha_i + \sum_k \gamma_{i,k} \ln(p_{ik}) + \sum_{j \neq i} \gamma_{i,j} \ln(p_j) + \beta_i \ln \left( \frac{E}{P^F} \right) \quad (6.4)$$

The Marshallian elasticities of demand are then calculated, as in Andayani and Tilley (1997), using the following formulae:

$$\varepsilon_{i,i} = 1 + \frac{\gamma_{i,i}}{w_i} - \beta_i \quad \text{(own-price elasticity)},$$

$$\varepsilon_{i,j} = \frac{\gamma_{i,j}}{w_i} - \beta_i \left( \frac{w_j}{w_i} \right) \quad \text{(cross-price elasticities of fresh product } i \text{ among sources),}$$
\[ \varepsilon_{i,j} = \gamma_{i,0} - \beta_i \left( \frac{w_i}{w_k} \right) \] (cross-price elasticity among fresh produce and sources), and

\[ \eta_i = 1 + \frac{\beta_i}{w_i}. \]

Since monthly data are utilized, consumption is unlikely to be in equilibrium due to habit persistence, adjustment costs, imperfect information and incorrect expectations, all of which may interfere with instant expenditure adjustment to prices and income changes. Nonstationarity and cointegration in the data could make the estimated parameters inconsistent. It is important that stationarity and cointegration tests are undertaken to determine whether the time series data are nonstationary and cointegrated. If the expenditure shares, prices, and real expenditure are cointegrated, a dynamic SDAIDS model is more appropriate. Although the inclusion of lagged dependent and lagged residuals in the dynamic model may have been more appropriate, owing to degrees of freedom limitations, we estimate a lagged static model.

### 6.3 Data

Monthly data from January 1989 to December 2008 are used to estimate the parameters of the Source-Differentiated AIDS model. The data are monthly quantities and Cost, Insurance, and Freight (CIF) import values obtained from the Foreign Agricultural Service of USDA. The tropical fresh fruit chosen for estimation include bananas, pineapples, papayas, mangoes/guavas, grapes, and other fruits. CIF values are chosen because they include shipping costs of the tropical fresh fruits.

The U.S. imports tropical fresh fruits from various sources. The top countries that supply tropical fresh fruit imports are identified for analysis. The source-differentiated imports of bananas are from Colombia, Costa Rica, Ecuador, Guatemala, and the rest-of-the-world (ROW).
Pineapples imports are sourced from Mexico, Honduras, Costa Rica, and the rest-of-the-world (ROW), while papayas are imported from Brazil, Mexico and the ROW. Mangoes/guavas import sources are sourced from Ecuador, Guatemala, Mexico, and the ROW. Other fresh fruits are not source differentiated. The summary of the sample source-differentiated shares, quantities and unit values is presented in Table 6.1.


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The prices of fresh fruits imports are not available, and, therefore, unit values are calculated and used as measures of market values of the imported fresh tropical fruits. The quantity data are in metric tons (MT), while the import values are in thousands of dollars (US$1000). The import price (unit value) of each source-differentiated fresh fruit is calculated by dividing the total monthly import value by the total monthly import quantity. In the event that prices were missing because of zero imports from a country, world import prices for the specific fresh fruit imports are utilized.

**Endogeneity Tests**

Since expenditures and prices are used to calculate the import real income/expenditure in equation 6.4, the expenditures and prices may not be exogenous. Another problem is that of import quantities being determined in advance through import quotas and SPS requirements, and then prices being determined by demand forces given the fixed supply. This would imply that the tropical fresh fruit prices are endogenous. Moreover, lags in production response to prices, such as in production of perennial fresh fruits, could also lead to simultaneity bias (Henneberry and Hwang 2007) in the short run.

The Wu-Hausman test was used to test for endogeneity in prices and expenditure variables. The test involves regressing potential endogenous variables on a set of instrumental variables (auxiliary regression). The instrumental variables chosen for the auxiliary regression are lagged source-differentiated prices and lagged expenditure shares. The residuals from the auxiliary regression are included in the SDAIDS model. A test on whether the coefficients of the residuals are statistically equal to zero concludes the endogeneity test. If the coefficients are found to be statistically significant, the conclusion is that endogeneity exists. The results of the
endogeneity test are presented in Table 6.2. From the results, there exists endogeneity in the expenditure, the prices of bananas from Ecuador, Guatemala, and the ROW; prices of papayas from Brazil, and prices of mangoes from Mexico and Guatemala. Test results suggest that pineapple prices and other fresh fruits are exogenous, implying that producers are able to respond to price changes in the short run.


<table>
<thead>
<tr>
<th>Variable</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expenditure</td>
<td>F = 3.4204***</td>
</tr>
<tr>
<td>Prices</td>
<td></td>
</tr>
<tr>
<td>Bananas</td>
<td></td>
</tr>
<tr>
<td>Colombia</td>
<td>F = 1.1361</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>F = 1.5846</td>
</tr>
<tr>
<td>Ecuador</td>
<td>F = 2.2751**</td>
</tr>
<tr>
<td>Guatemala</td>
<td>F = 2.2950**</td>
</tr>
<tr>
<td>ROW</td>
<td>F = 3.2838***</td>
</tr>
<tr>
<td>Pineapples</td>
<td></td>
</tr>
<tr>
<td>Mexico</td>
<td>F = 0.3233</td>
</tr>
<tr>
<td>Honduras</td>
<td>F = -0.1073</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>F = -1.2881</td>
</tr>
<tr>
<td>ROW</td>
<td>F = -0.4486</td>
</tr>
<tr>
<td>Papayas</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>F = 3.5429***</td>
</tr>
<tr>
<td>Mexico</td>
<td>F = 1.0136</td>
</tr>
<tr>
<td>ROW</td>
<td>F = -1.3628</td>
</tr>
<tr>
<td>Mangoes/Guavas</td>
<td></td>
</tr>
<tr>
<td>Ecuador</td>
<td>F = -0.3498</td>
</tr>
<tr>
<td>Guatemala</td>
<td>F = -1.9597</td>
</tr>
<tr>
<td>Mexico</td>
<td>F = -3.3260**</td>
</tr>
<tr>
<td>ROW</td>
<td>F = 0.5283</td>
</tr>
<tr>
<td>Other Fruits</td>
<td></td>
</tr>
<tr>
<td>World</td>
<td>F = 0.9683</td>
</tr>
</tbody>
</table>

***, **, and * denote significance at the 1 %, 5%, and 10% levels, respectively.
6.4 Estimation Results

Since some of the prices and expenditures were found to exhibit endogeneity, the SDAIDS model is estimated using three-stage least squares (3SLS) method of estimation. Because tropical fresh fruit shares equal to one, the import expenditure share equation for the ROW was excluded from estimation to avoid singularity. The coefficients of the dropped equation were then calculated using the adding-up restriction. Results of the estimated SDAIDS are presented in Table 6.3.

Commodities with significant the intercepts, \( \alpha_i 's \) include bananas from Colombia, Costa Rica, Ecuador, and the ROW, pineapples from Costa Rica, mangoes/guavas from Ecuador, Mexico, and the ROW, Papayas from the ROW, and all other fruit imports. The real expenditure parameters for mangoes/guavas from Mexico, Ecuador, and the ROW, papayas from Mexico and the ROW, pineapples from Costa Rica, and all other fresh fruit imports are positive and significant. This suggests that these commodities are luxury goods confirming that tropical fruit imports are considered exotic. Bananas from Colombia, Costa Rica, and the ROW are shown to have negative and significant real expenditure coefficients implying that they are necessities. Again this finding is consistent with the fact that bananas are very popular fruits among U.S. consumers and considered staples.

Own-price coefficients that are statistically significant include bananas from Guatemala, pineapples from Mexico, Honduras, and Costa Rica, papayas from Mexico, mangoes/guavas from Guatemala, Mexico, and the ROW. The estimated cross-price coefficients for Colombian and Costa Rican bananas, Ecuadorian and Guatemalan bananas, Costa Rican and the ROW bananas, Honduran and the ROW pineapples, Brazilian and the ROW papayas, and Ecuadorian
and Mexican mangoes/guavas are positive and significant. This implies that these commodities are substitutes, which is expected.

The uncompensated and compensated elasticities of demand were calculated at sample means and are presented in Tables 6.4 and 6.5, respectively. The uncompensated and compensated elasticities are nearly identical, most likely because fresh fruits consumption comprises a very small proportion of U.S. consumers’ expenditures. We therefore concentrated only on the compensated elasticities for our discussion. All the source-differentiated expenditure elasticities are positive, with the exception of the insignificant expenditure elasticities for bananas from Colombia and the ROW. Except for bananas, all the fresh fruit sources’ expenditure elasticities are greater than one. This result is consistent with the general knowledge that excluding bananas, which are staple and popular fresh fruits in the U.S., tropical fresh fruits are exotic and luxury commodities to the American consumer.

Within bananas’ differentiated sources, only Guatemalan bananas have a significant, elastic expenditure elasticity of 1.1756. This finding suggests that U.S. tropical fresh fruit consumers have a preference for Guatemalan bananas over bananas from Ecuador, Colombia, Costa Rica, and the ROW. The rest of bananas sources’ expenditure elasticities are very inelastic, suggesting that bananas are staple food commodities.

Papayas, pineapples, mangoes/guavas, and all the other fresh fruit imports are luxury commodities, as are shown by the positive estimated expenditure elasticities that are greater than one and statistically significant over all the sources (except for Mexican pineapples, Brazilian papayas, and Guatemalan mangoes/guavas, which are greater than one but statistically insignificant). For pineapples, estimation results show that Honduras, Costa Rica, and the ROW have positive and significant expenditure elasticities of 1.492, 2.174, and 1.4565, respectively.
These elasticities suggest that Costa Rican pineapples are preferred over other pineapples. The estimated expenditure elasticities for papayas differentiated sources show U.S. tropical fresh consumers have a preference for ROW, and Costa Rican papayas are preferred to Brazilian papayas, with the ROW being the most preferred.

The source-differentiated expenditure elasticity estimates for mangoes/guavas show that Mangoes/guavas are strong luxury goods. The estimated expenditure elasticities for mango/guava range from 1.9719 for Mexico to 6.0297 for ROW. Expenditure elasticities for Ecuador and the ROW mangoes are 4.0617 and 6.097, respectively, implying that they are highly preferred by U.S. tropical fresh fruit consumers over mangoes/guavas from Guatemala and Mexico. Other fresh fruit imports have an elastic expenditure at 2.3855.

Consistent with economic theory, the estimated own-price elasticities of the SDAIDS have the expected negative sign, with the exception of Mangoes/guavas from the ROW and the insignificant own-price elasticities for Guatemalan bananas and mangoes/guavas, Costa Rican pineapples, and Honduras. Among these, own-price elasticities for mangoes/guavas from Ecuador and Mexico and papayas from the ROW are greater than one and statistically significant. Among these own-price elasticities that are greater than one include: mangoes/guavas produced in Ecuador, Guatemala, Mexico, and the ROW; papayas from Brazil and ROW; and bananas from Colombia. This result suggests that these fresh fruits are very sensitive to price changes. Inelastic and significant own-price elasticities estimates were found for bananas from Ecuador, Costa Rica, and the ROW, pineapples from Honduras, and the ROW, and all other fresh fruit imports. Surprisingly, mangoes/guavas from the ROW are found to have a large, positive, and significant own elasticity suggesting that they are giffen goods.
The cross-price elasticities indicate whether tropical fresh fruits from various sources have substitutability and complementary demand relationships however the interpretation should be taken with some caution. Tropical fresh fruit production and importations are controlled three U.S. multinational companies namely Del Monte, Chiquita, and Dole and source-differentiation could also imply the companies’ country substitutability. However, these companies are expected to make production locations and imports sources based on production and shipping cost, and most important consumer quality preferences and so the consumer preferences of source-differentiated fresh fruits are indirectly implied.

Within tropical fresh fruits, bananas are shown to have the highest competition amongst sources. The cross-price elasticities of demand of bananas from Ecuador and those from Costa Rica, Colombia, and the ROW, and bananas from the ROW and Colombia, Costa Rica, and Ecuador are found to be positive and statistically significant. This implies that bananas from these sources are significant substitutes and with each other. The highest competition amongst bananas sources is between Ecuador and Colombia, and Costa Rica and ROW, based on the magnitude of the cross-price elasticities. Significant complementary bananas sources include Guatemala and Ecuador, and Colombia and Costa Rica as the respective cross-price elasticities are negative and significant. These results confirm prior expectations for steep competition among U.S. banana suppliers.

For pineapples, significant source substitutes are Mexico and Costa Rica, and Costa Rica and the ROW, while complementary pineapple sources include Costa Rica and Honduras, and Honduras and the ROW. The results also show that papayas from Brazil and the ROW are very strong substitutes, as the cross-price elasticities of demand are positive, greater than one, and
significant. Regarding the mango/guava market, significant substitutes include Mexico and Ecuador, and complementary mangoes/guavas sources include Guatemala and Mexico.

Among cross-commodity relationships, many pineapples, mangoes/guavas, and papaya sources are shown to be significant substitutes for bananas sources. This result is expected, given the growing entry of other tropical fresh fruits into the U.S. market and the subsequent reduction of the market share for bananas in the past decade. Colombian bananas are shown to be substitutes with pineapples from Mexico and Costa Rica, mangoes from Mexico, and all the other fresh fruit imports, and they demonstrate a weak complementary relationship with Ecuador mangoes and ROW papayas.

Costa Rican bananas are substitutes with pineapples from Mexico, Honduras, and the ROW, papayas from Mexico and the ROW, mangoes/guavas from Mexico, and all other fruit imports. Bananas from Ecuador show a substitutability relationship with Mexican mangoes, ROW papayas and other fruits and demonstrate a weak complementary relationship with Mexican pineapples and papayas. Guatemalan bananas show a weak complementary relationship with mangoes from Guatemala and Mexico and pineapples from Mexico while showing substitutability with Mexican mangoes, ROW papayas, and other fresh fruits. Bananas from the ROW are found to be substitutes with pineapples from Honduras, mangoes from Ecuador, and other fresh fruit imports, and complementary with Brazilian papayas.

Among pineapple and papaya sources, significant substitutes include Mexican papayas and pineapples (1.1693), and Costa Rican pineapples with Brazil papayas (9.2115), and ROW pineapples with Mexican papayas. There are no significant complementary relationships between papaya and pineapple sources. Similarly, there are significant substitute relationships between pineapple sources and mango/guava sources or other fruits. However, complementary
relationships exist for pineapples from the ROW and for Mexican and the ROW mangoes, other fruit imports, Mexican pineapples and Guatemalan mangoes, and other fruit imports.

With regard to papaya and mango sources, Mexican papaya show a significant complementary relationship with Guatemalan and Mexican mangoes, as are the ROW papayas and other fresh fruit imports. Fresh mango/guava differentiated-source cross-price elasticities show that all the other fresh fruit imports are significant substitutes with mangoes from Guatemala, Mexico, and the ROW. Except for Pineapples from Mexico and the ROW, and papayas from the ROW, other fresh fruits are shown to compete with most tropical fresh fruit imports, as most of the cross-price elasticities are positive and significant at the 1 and 5 percent levels.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>BANCO</th>
<th>BANCR</th>
<th>BANCN</th>
<th>BANGT</th>
<th>BANROW</th>
<th>PINMN</th>
<th>PINMCR</th>
<th>PINMORE</th>
<th>PINPAP</th>
<th>PINPAX</th>
<th>PINPAXO</th>
<th>MANCN</th>
<th>MANGNT</th>
<th>MANMX</th>
<th>MANROW</th>
<th>OTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>1.422***</td>
<td>1.9172***</td>
<td>2.1663*</td>
<td>-0.1462</td>
<td>1.8707***</td>
<td>0.0351</td>
<td>-0.0029</td>
<td>-0.6388***</td>
<td>-0.0225</td>
<td>-0.0338</td>
<td>-0.0589</td>
<td>-0.0575*</td>
<td>-0.0508**</td>
<td>0.0233</td>
<td>0.0954***</td>
<td>0.02935**</td>
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<tr>
<td>$\beta$</td>
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<td>0.0099</td>
<td>-0.0002</td>
<td>0.0125</td>
<td>0.0049</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
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<tr>
<td>$\gamma$</td>
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<td>0.0039</td>
<td>0.0074</td>
<td>-0.0001</td>
<td>0.0039</td>
<td>0.0019</td>
<td>0.0001</td>
<td>0.0001</td>
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<td>0.0001</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.0004</td>
<td>0.0039</td>
<td>0.0074</td>
<td>-0.0001</td>
<td>0.0039</td>
<td>0.0019</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
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<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Below the estimated parameters, are the respective standard errors. PIN=Pineapples, BAN=Bananas, PAP=Papaya, MAN=Mango/Guava, OTH=All other fresh fruits, EC=Ecuador, CO=Colombia, CR=Costa Rica, GT=Guatemala, MX=Mexico, HN=Honduras, BR=Brazil, and InP=price log.
Below the estimated elasticities, are the respective standard errors and *, **, and *** are represent significance at the 10 percent, 5 percent and 1 percent levels, respectively. Significant substantive and complementory goods are marked by red and blue colors respectively.

<table>
<thead>
<tr>
<th>Fruits</th>
<th>Bananas</th>
<th>Pineapples</th>
<th>papaya</th>
<th>Mangos/Guavas</th>
<th>Other Fruits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Colombia</td>
<td>Costa Rica</td>
<td>Ecuador</td>
<td>Guatemala</td>
<td>ROW</td>
</tr>
<tr>
<td>Colombia</td>
<td>-1.1054***</td>
<td>-0.3097***</td>
<td>0.9598***</td>
<td>0.2184</td>
<td>0.2818*</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>-0.4999***</td>
<td>-0.9346***</td>
<td>0.0209**</td>
<td>-0.0015</td>
<td>0.5838***</td>
</tr>
<tr>
<td>Ecuador</td>
<td>0.0720</td>
<td>0.1060</td>
<td>0.0911</td>
<td>0.0798</td>
<td>0.0864</td>
</tr>
<tr>
<td>Guatemala</td>
<td>0.5368***</td>
<td>0.1907***</td>
<td>0.0706***</td>
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<tr>
<td>Mexico</td>
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</tr>
<tr>
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<td></td>
<td>0.1217</td>
<td>0.1206</td>
<td>0.1491</td>
<td>0.1712</td>
<td>0.1330</td>
</tr>
</tbody>
</table>

Below the estimated elasticities, are the respective standard errors and *, **, *** are represent significance at the 10 percent, 5 percent and 1 percent levels, respectively. Significant substitute and complementary goods are marked by red and blue colors respectively.
6.5 Conclusions

In this chapter, a source-differentiated AIDS model is utilized to analyze the U.S. demand for tropical fresh fruits and to determine demand relationships of the leading U.S. tropical fresh fruit sources. The fresh fruits chosen for the study include fresh fruit imports of bananas, pineapples, papaya, mangoes/guavas, and other fresh fruit imports. The selected sources of bananas are Colombia, Costa Rica, Ecuador, Guatemala, and the ROW. Fresh pineapple sources are Mexico, Honduras, Costa Rica, and the ROW. Papaya sources are identified as Mexico, Brazil, and the ROW, while mangoes sources are Mexico, Guatemala, Ecuador, and the Row. For completeness, all the other fresh fruit imports are included. In total, sixteen (16) import share equations are formulated.

Although the data showed nonstationarity properties, an attempt to estimate a dynamic AIDS model proved futile, due to degrees of freedom limitations. A static AIDS model with lagged prices and shares was used instead. Endogeneity tests also showed that simultaneity exists in some of the prices and expenditures, justifying the use of an iterative 3SLS estimation method.

Results show that most of the source-differentiated fresh fruits expenditure shares are significant, positive, and very elastic implying that consumer incomes are a major determinant of tropical fresh fruit import demand. With the exception of bananas sources, tropical fresh fruits are found to be luxury commodities. For bananas, the expenditure elasticities estimates show that U.S. consumers prefer Guatemalan and Costa Rican bananas to the other sources. With regard to pineapples, Costa Rican, the ROW, and Honduras produced fruits are preferred in that order. Among mango sources, U.S. consumers have strong preference for ROW, Ecuador, and...
Mexican produced mangoes over Guatemalan mangoes. Papayas from the ROW are the most preferred.

A competitive relationship exists between bananas from Ecuador and Colombia, Ecuador and Costa Rica, and the ROW and Colombia, Costa Rica, and Ecuador. Surprisingly, bananas from Costa Rica and Colombia and from Guatemala and Ecuador are the only complementary commodities within the group. Bananas are also shown to be facing a lot of competition from the other tropical fresh fruits, particularly most pineapple and mango sources, as well as from all the other fresh fruit imports.

Strong competitive relations exist between papayas from Brazil and the ROW, pineapples from Costa Rica and Mexico and those from Costa Rica and the ROW, and mangoes from Mexico and Ecuador. Complementary relationships also exist between Guatemala and Mexican mangoes and pineapples from Honduras and Costa Rica and the ROW.

The findings from this study have some crucial implications for the countries that supply the U.S. with these tropical fresh fruits. The countries of origin might be interested in finding out by how much they could increase their market share in the U.S. and especially what might be the impact of price changes of their commodity. For example, Mexico is the leading supplier of mangoes/guavas to the United States, but, since 2000, it has been losing its market share to Ecuador and the ROW (Figure A.1.15 in the Appendix). Mexico could utilize price competition strategies to retain and regain its U.S. mango market share. Based on our price elasticity of demand estimates, if Mexico reduces the price of its mangoes prices by 1 percent, its mango expenditure share in the U.S. will increase by 1.6073 percent. As a result, Ecuador, which is its sole competitor in the U.S. mango market, would lose 1.1650 percent of U.S. mango expenditure
share. Mexico would also gain 0.2066 percent of the U.S. papaya expenditure share from this action, because its mangoes and papayas are significant complementary goods. Mexico’s pricing decision would further negatively impact U.S. expenditure shares of banana supplying countries except for Guatemala as they are significant substitutes. However, Mexico is not a major player in the banana market in the U.S. and has nothing to lose. Similarly, Colombia, Costa Rica, and Ecuador can utilize price competition in the banana market to capture more market share.

Based on the expenditure, own-price elasticities, and cross-price elasticities, countries which supply mangoes/guavas and papayas appear to be more capable of benefiting from price competition. Despite the fact that some of these results differed from our expectations, the study provides source-differentiated elasticity estimates for U.S. fresh fruit imports for many topical fruits, such as mangoes, papaya, and pineapples, which are unavailable in the existing literature. These results provide important market information to source/origin countries and the main tropical fruit trade players in those countries.
CHAPTER 7
SUMMARY AND CONCLUSIONS

7.1 Trigonometric and Error Correction AIDS Model Results Comparisons

This dissertation comprises four studies on U.S. demand for fresh tropical fruit and vegetable imports using different approaches and data composition. In the first study (Chapter 3), a trigonometric AIDS model is utilized to capture seasonality and trend in the selected tropical fruit and vegetable import demand. The second and third studies (Chapters 4 and 5) use an error correction specification of the AIDS model in estimating the demand for tropical fresh fruits and vegetables, respectively, to avoid inconsistency of the estimates due to nonstationarity in the data. The analyses in these three studies produced similar results in some cases and contradicted in other areas. For example, NAFTA was shown to favorably impact demand for fresh vegetable imports in the trigonometric AIDS specification, but in the error correction specification it was insignificant. Both the trigonometric and ECM versions, of AIDS model estimations showed that NAFTA is not important in the demand for tropical fresh fruits, largely because they originate mainly from non-NAFTA countries.

The expenditure elasticities of demand were found to be positive and significant in both approaches. However, most expenditure elasticities were larger in magnitude in the trigonometric AIDS model. Bananas, avocados, tomatoes and asparagus were found to be luxury goods in the trigonometric AIDS model. However, bananas are necessities in the ECM version. Fresh grape import expenditure elasticities ranged from 0.9533 in the trigonometric AIDS model to 3.3193 in the error correction AIDS model. In the fresh vegetable ECM- AIDS
model, expenditure elasticities of demand were shown to be lower than in the trigonometric model. All fresh vegetable imports were shown to be necessities in the error correction model.

Monthly own-price elasticities of demand for bananas were -0.0952 in the ECM model and -0.5416 in the trigonometric AIDs model. Own-price elasticities of demand were very comparable for pineapples and avocados in both studies. For avocados, the own-price elasticities were -0.8823 in the trigonometric specification and -0.8524 in the ECM model, while for pineapples they were -0.2330 and -0.3883, respectively. In the error correction model, papayas, mangoes are price elastic, while in the trigonometric model none of the fruits are price elastic. For vegetables, price elastic vegetable imports included cucumbers in the ECM version of the AIDS (-1.0987) and tomatoes in the trigonometric model (-1.0995).

The difference in results could be due to omitted variables, because in the trigonometric model, only imports were considered for analysis, while in the ECM model U.S. domestic supply and other fresh fruit imports were included. Also, in the trigonometric model quarterly data is used while in the ECM model monthly data is utilized. The use of monthly shipments for U.S. supply could also bias estimates.

7.2 Summary

The demand for tropical fresh fruits and fresh vegetables has risen in the U.S. over the last three decades due to a combination of several demand factors. The purchasing power of U.S. consumers rose over these years due to rising personal incomes, while research evidence in health, food, and nutrition also modified U.S. consumer perceptions and habits toward consuming more fresh fruits and vegetables. The heightened influx of an immigrant population accustomed to fresh-produce diets, mainly Asian, Hispanic, African, and the Caribbean island populations, has also impacted the demand for fresh fruits. Supply factors, such as the climate
and a limited farm labor supply, on the other hand, have restricted the ability of U.S. producers to respond to the rising demand, making imports the more viable solution to satisfy the rising demand for fresh fruits and vegetables. Free trade agreements, such NAFTA and CAFTA, and technological advances in shipping and handling of fresh produce have also provided more access to fresh fruit imports over longer periods of time. Thus, the importance of imports to U.S. fresh fruit and vegetable consumption continues to grow.

Between 1990 and 2006, annual U.S. imports of fresh fruits and vegetables rose from 67 to 77.8 million U.S. constant dollars. Consequently, the import share of U.S. fresh fruit and vegetable consumption rose significantly, with the import share for non-citrus fruits rising to 53 percent. Despite the growing importance of tropical fresh fruit and vegetable imports in the U.S. fresh produce market, few studies have examined demand for fresh fruit imports, particularly tropical fruits. Most of the available literature focuses on the competitiveness of U.S. fresh produce in general, or the domestic market and the main U.S. export markets for fresh produce. Little reference has been made to the U.S. fresh fruit import market, except for bananas, which has been studied extensively, perhaps due to its dominance in the U.S. fresh fruit market.

This study analyzes U.S. import demand for the top tropical fresh fruits and vegetables, which comprise the bulk of U.S. fresh fruit and vegetable imports. We further examine the demand relationships of tropical fresh fruits from the top sources of the major U.S. tropical fresh fruit imports. Chapter one of this study introduces the research issues and objectives of the study. The second chapter covers a review of relevant literature and model approaches of analyzing import demand systems.
7.3 Conclusions

In Chapter three, we examine the U.S. demand for selected tropical fresh fruits and vegetables using an LA/AIDS model with price homogeneity and symmetry imposed. The fresh fruits and vegetables selected for the study are bananas, pineapples, papayas, mangoes/guavas, grapes, tomatoes, cucumbers, peppers, and asparagus. To capture the seasonality effects, a spectral approach is used by introducing trigonometric seasonality into the model. The trigonometric seasonality coefficients confirmed the presence of seasonality in all the tropical fresh fruit and vegetable import shares, and all the fresh fruits and vegetables showed a positive trend, except for bananas, which had a negative and significant trend. NAFTA trade policy significantly impacted expenditure shares for papayas, tomatoes, and peppers, due to improved accessibility, but negatively impact bananas and pineapples due to the entry of more varieties of fresh produce. Most of the fresh fruit and vegetable imports significantly respond to changes in real income/expenditure and to price changes.

In Chapter four, we estimated the demand for tropical fresh fruits using a dynamic AIDS model. The fresh fruits chosen for the study include bananas, pineapples, papayas, mangoes/guavas, grapes, avocados and other fresh fruit imports. Nonstationarity and cointegration in the data series justified an error correction specification of the AIDS model. The findings from the study showed that NAFTA is not influential in tropical fresh fruit imports, perhaps because these commodities originate largely from non-NAFTA countries with the exception of mangoes. All the tropical fresh fruit import expenditure shares positively and significantly respond to real income/expenditures, implying that they are normal goods, and consumer income is a major determinant of U.S. tropical fresh fruit imports.
Fresh grapes and other fresh fruit imports are found to be luxury commodities, while bananas are staples, as has been shown in the existing literature. Papayas and Mangoes/guavas are price elastic, whereas bananas, pineapples, U.S. grapes, and other fruit imports are price inelastic. Avocados are substitutes for bananas, papayas, mangoes/guavas, and fresh grape imports. Fresh grape imports are also significant substitutes to domestic grapes, implying that besides supplementing supply during U.S. production off-season in winter, the imported fresh grapes compete with U.S. produced grapes in summer and fall seasons. This is understandable since fresh grape imports are mainly from Chile and Mexico where they are produced year round in Chile and some parts of Mexico. Other significant substitutes include bananas and mangoes/guavas, pineapples and papayas, and mangoes/guavas and grape imports. Complementary fresh fruits include bananas and grape imports, avocados and other fruit imports and U.S. grapes. To some extent, these findings rekindle fresh fruit consumption patterns. For example, bananas and fresh grapes are both often eaten as snacks and can be consumed together.

Chapter five presents a dynamic, source-differentiated AIDS model estimation of selected fresh vegetables that include fresh tomatoes, peppers, cucumbers, and asparagus. The origin of the fresh vegetables is categorized into U.S. domestic source and total imports. All the data series were found to be nonstationary and cointegrated, and therefore an ECM-AIDS model was used. Most fresh vegetable imports were shown to be more price elastic than their domestic vegetable cohort. Cucumbers and asparagus are shown to be price elastic, and all the fresh vegetables were found to be responsive to real expenditure changes, as expected. Most of the U.S. fresh vegetable imports were shown to significantly compete with domestic fresh vegetables, and in particular with tomatoes, peppers, and cucumbers. Asparagus, on the other
hand, show no significant relationship between imports and U.S. domestically produced
commodities. This implies that asparagus is the only fresh vegetable commodity whose imports
are independent of local produce.

In chapter 6, a source-differentiated AIDS model is used to analyze the relationships
between U.S. tropical fresh fruit imports from various sources. Bananas, pineapples, papaya,
mangoes/guavas, and other fresh fruit imports are selected, and their respective sources
differentiated by the top countries of origin. Due to endogeneity in expenditure and prices, an
iterative 3SLS method of estimation is used. Results show that most of the source-differentiated
tropical fresh fruit imports are luxury commodities, as their expenditure elasticities are very
elastic, except for bananas, which appear to be a staple. Within commodity groups, U.S
consumers have a preference for Guatemalan bananas, Costa Rican pineapples, and ROW
papayas and mangoes over commodities from other sources. Honduran pineapples, Mexican
papayas, Ecuadorian and Mexican mangoes/guavas, and other fruit imports are also highly
sought after, as their expenditure elasticities are greater than one in magnitude.

The cross-price elasticities from the source-differentiated AIDS model also show a strong
competitive relationship between bananas from Ecuador and Colombia, Ecuador, and Costa
Rica, Colombia and the ROW. Bananas from the ROW also show a competitive relationship
with those from Costa Rica and Ecuador. Bananas appear to be facing a lot of competition from
the other tropical fresh fruits, mainly mangoes/guavas and pineapples, which is evident from the
positive and significant cross-price elasticities. This is consistent with our expectations, due to
the declining banana import share, which is documented in most recent literature.

Results also show that papayas from Brazil and the ROW, pineapples from Costa Rica
and Mexico and from Costa Rica and the ROW, and mangoes/guavas from Mexico and Ecuador
are substitutes and therefore are competitors. Complementary relationships are found to exist between mangoes/guavas from Guatemalan and Mexico and pineapples from Honduras, Costa Rica and the ROW. Other commodities that are shown to have complementary relationships include bananas from Costa Rica and Colombia and those from Guatemala and Ecuador.

The findings from this study provide some insights into demand relationships for tropical fresh fruit and vegetable imports in the U.S. The key market players in fresh fruit and vegetable trade and the countries of origin for these commodities might use the findings in determining how much they could increase their market share and if price competition is a viable option. The U.S. might also find the results useful in deciding which fresh produce commodities need assistance in terms of research and infrastructure development to enhance the ability of the fresh fruit and vegetable industry to fairly compete with imports and also identify the exotic fresh fruits that are in demand for domestic field trials.

7.4 Limitations of Study

One of the major limitations of this study is the lack of data on monthly consumption of domestically produced fresh fruits and vegetables. Monthly fresh fruit and vegetable shipments are available from the Agricultural Marketing Service and serve as proxies of the U.S. monthly consumption. Another limitation is the dominance of U.S. fresh sector by a few U.S. multinational companies which decide where to produce and ship each commodity, and so the source-differentiation is not purely a consumer decision.

Aggregation is also a likely source of bias in our study because of ignoring preferences based on quality of different varieties within a commodity. Different varieties of tomatoes, pineapples, papayas, mangoes, and in essence all the fresh produce commodities fetch different prices due to quality differences, but that was not captured in our study.
Despite these weaknesses, the study provides some important insights into the demand relationships for fresh fruit and vegetable imports. It contributes to the existing literature by providing elasticity estimates for the major tropical fresh fruit and vegetable imports.
REFERENCES


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APPENDICES

A. IMPORT QUANTITY AND EXPENDITURE SHARE GRAPHS

Figure A.1.1. U.S. Tropical Fresh Fruit and Vegetable Imports by Quarter in Thousand Metric Tonnes (1000 MT), 1989:1-2008:3
Figure A.1.2. Quarterly Expenditure Shares of U.S. Fresh Tropical fruits and Vegetable Imports, 1989:1-2008:3.

Figure A.1.3. U.S. Domestic and Import Monthly Quantities of Tropical Fresh Fruit Imports in Thousand Metric Tonnes (1000 MT), 1989:1-2008:12
Figure A.1.4. U.S. Domestic and Import Monthly Expenditure Shares of Tropical Fresh Fruit Import, 1989:1-2008:12

Figure A.1.5. U.S. Domestic and Import Monthly Quantities of Fresh Vegetable Import in Thousand Metric Tonnes (1000 MT), 1989:1-2008:12
Figure A.1.6. U.S. Domestic and Import Monthly Expenditure Shares of Fresh Vegetable Imports, 1989:1-2008:12

Figure A.1.7. U.S. Domestic and Import Monthly Quantities of Fresh Tomatoes in Thousand Metric Tonnes (1000 MT), 1989:1-2008:12
Figure A.1.8. U.S. Domestic and Import Monthly Quantities of Fresh Peppers in Thousand Metric Tonnes (1000 MT), 1989:1-2008:12

Figure A.1.9. U.S. Domestic and Import Monthly Quantities of Fresh Cucumbers in Thousand Metric Tonnes (1000 MT), 1989:1-2008:12
Figure A.1.10. U.S. Domestic and Import Monthly Quantities of Fresh Asparagus in Thousand Metric Tonnes (1000 MT), 1989:1-2008:12

Figure A.1.11. U.S. Monthly Imports of Other Fresh Vegetables in Thousand Metric Tonnes (1000 MT), 1989:1-2008:12


Figure A.1.15. U.S. Fresh Mango/Guavas Monthly Imports by Country of Origin in Thousand Metric Tonnes (1000 MT), 1989:1-2008:12
B. GLOSSARY

**Banana Exporting Countries:** These are the world’s leading banana producing and exporting countries. They include Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Panama, Philippines. They are the leading exporters of fresh fruits and vegetables into the U.S.

**NAFTA:** North American Free Trade Agreement (NAFTA) is a comprehensive economic and trade agreement that establishes a free-trade area encompassing Canada, Mexico, and the United States. Much of NAFTA is structured as three separate bilateral agreements, one between Canada and the United States, a second between Mexico and the United States, and a third between Canada and Mexico. The first accord is the Canada-U.S. Free Trade Agreement (CUSTA), which took effect on January 1, 1989, and was subsumed by NAFTA. The second and third agreements are found in NAFTA itself, which took effect on January 1, 1994.
Southern-Hemisphere Countries: In this study, southern hemisphere refers to countries that are located south of Cancer latitude. These countries are located either within the tropics like most of Southern America countries or in geographical southern hemisphere such South Africa.

Fresh Produce: This term refers to fruits and vegetables that are marketed and consumed in their fresh form. It does not include processed, frozen, preserved or dried fruits and vegetables.

Fresh Tropical Fruits and Vegetables: These are fresh fruits and vegetables that, due to climatic conditions are produced in tropical regions. Tropical fresh fruits constitute the bulk of U.S. fresh fruit imports. They include, bananas, guavas, mangoes, pineapples, papayas, and avocados. Only Florida, Hawaii and California states in the U.S. have attempted a limited production of pineapples, papayas, avocados, mangoes and to some extend bananas. Studies for the past six years by UGA scientists show that banana production for ethnic and niche markets has potentials of becoming a cash crop in Georgia and the Southeast. Otherwise, supply is almost exclusively external. Tropical fresh vegetables like tropical fresh fruits grow well in tropical regions. Such vegetables include tomatoes, peppers, cucumbers and asparagus.

However, because vegetables require a short time to produce, during summer and fall when it is warm, the U.S. produces most of its fresh vegetables requirements but relies on imports during cold seasons.


WTO: World Trade Organization (WTO), a global trade organization that governs trade across nations and is advocating for free trade. It was designed to supervise and liberalize international trade. The WTO came into being on 1 January 1995, and is the successor to the General
Agreement on Tariffs and Trade (GATT), which was created in 1947, and continued to operate for almost five decades as a *de facto* international organization.