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U.S. Mushroom Import Demand Estimation with Source Differentiated AIDS and Rotterdam Models

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Source Differentiated AIDS and Rotterdam Models

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While technically considered as fungi, mushrooms are often classified as vegetables because they provide many of the nutritional attributes of produce as well as meat, beans, and grains. The U.S. is the largest consumer of mushrooms and the share of imports in total consumption of mushrooms has been rising and will likely continue to rise as U.S. consumers increasingly adopt healthier diets. While most of U.S. fresh mushroom imports are from Canada, China, Mexico and South Korea, most of U.S. canned mushroom imports are from China, India, Indonesia, and the Netherlands.

The contribution of this thesis is to provide the first-ever estimates of import demand elasticities for fresh and canned mushrooms during the period of 2002-2015 by 1) first using a source-differentiated Almost Ideal Demand System (AIDS) model and a source-differentiated Rotterdam model; and 2) selecting between the two models based on two specification tests.

Several findings and implications are in order. First, demand for Canadian fresh mushrooms is more inelastic than demand for Chinese canned mushrooms. This means that while Canada, the leading exporter of fresh mushrooms, may gain more revenue from rising mushroom prices; China, the leading exporter of canned mushrooms, may

lose. Second, the expenditure elasticity of fresh mushroom imports from Canada is inelastic and the expenditure elasticity of canned mushroom imports from China is elastic. This means that Chinese exporters stand to gain more than Canadian exporters from rising U.S. spending on mushrooms.

ACKNOWLEDGMENTS

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OUTLINE

LIST OF TABLES iv

LIST OF FIGURES vi

CHAPTER 1: INTRODUCTION 1

1.1 Statement of the Problem 1

1.2 Objectives and Methodology 3

1.3 Organization of the Study 4

CHAPTER 2: OVERVIEW OF U.S. MUSHROOMS MARKET 5

2.1 Production 5

2.2 Consumption 8

2.3 Trade 9

CHAPTER 3: LITERATURE REVIEW 11

CHAPTER 4: MODEL SPECIFICATION AND SELECTION 13

4.1 Model Specification 13

4.1.1 A Source-Differentiated Almost Ideal Demand System (AIDS) Model 14

4.1.2 A Source-Differentiated Rotterdam Model 16

4.2 Model Selection 17

4.2.1 Testing the AIDS Specification 19

4.2.2 Testing the Rotterdam Specification 19

CHAPTER 5: DATA, ESTIMATION PROCEDURE, AND RESULTS 21

5.1 Data 21

5.2 Estimation Procedure 28

5.3 Results 28

5.3.1 Elasticity Estimates 28

5.3.2 Specification Tests and Model Selection 34

CHAPTER 6: SUMMARY AND CONCLUSIONS 45

REFERENCES 48

LIST OF TABLES

Table 1. HTS numbers and definitions for fresh and canned mushrooms 23

Table 2. Summary statistics for expenditure shares of U.S. mushrooms imports 24

Table 3. Summary statistics for prices of U.S. mushrooms imports 27

Table 4. Estimated expenditure elasticities: source-differentiated AIDS and Rotterdam models 30

Table 5a. Estimated price elasticities of demand for fresh mushrooms: source-differentiated AIDS and Rotterdam models 32

Table 5b. Estimated price elasticities of demand for canned mushrooms: source-differentiated AIDS and Rotterdam models 33

Table 6. Testing the AIDS and Rotterdam specifications 35

Table 7. Estimated expenditure elasticities: source-differentiated AIDS model and First-differenced version of source-differentiated AIDS model 36

Table 8a. Estimated price elasticities of demand for fresh mushrooms: source-differentiated AIDS model and first-differenced version of source-differentiated AIDS model 40

Table 8b. Estimated price elasticities of demand for canned mushrooms: source-differentiated AIDS model and first-differenced version of source-differentiated AIDS model 41

Table 9. Weighted mean square error: source-differentiated AIDS model and first-differenced version of source-differentiated AIDS model 42

Table 10. Price elasticities of U.S. mushrooms import demand using first-differenced version of source-differentiated AIDS model 43

Table 11. Summary of price and expenditure responsiveness of U.S. fresh and canned mushroom import demand 44

LIST OF FIGURES

Figure 2.1. Number of mushroom growers in the U.S. (2000-2015).................................. 6

Figure 2.2. Mushrooms production in the U.S. (1995-2015)... 7

Figure 2.3. Mushrooms consumption in the U.S. (1995-2015) 8

Figure 2.4. Share of mushroom imports in total consumption in the U.S. (1995-2015) .. 10

Figure 5.1 Percentage of U.S. fresh mushrooms imports from different sources (2002-2015). 25

Figure 5.2. Percentage of U.S. canned mushrooms imports from different sources (2002-2015) 26

CHAPTER 1: INTRODUCTION

1.1 Statement of the Problem

While technically considered as fungi, Mushrooms are often classified as vegetables because they "provide many of the nutritional attributes of produce, as well as attributes more commonly found in meat, beans or grains. Mushrooms are low in calories, fat-free, cholesterol-free, gluten-free, and very low in sodium, yet they provide important nutrients, including selenium, potassium, riboflavin, niacin, and vitamin D" (Mushroom Council). Several preclinical and clinical studies indicate that the consumption of mushrooms may support oral health, weight management, and healthy immunity (Signoretto et al., 2011; Zaura et al., 2011; Poddar et al., 2013; Roupas et al., 2012). Other studies suggest that consumption of mushrooms may decrease the risk of certain diseases, including breast and prostate cancer (Chen et al., 2006; Shin et al., 2010; Tufts Journal). That, combined with more environmentally friendly production methods have resulted in increased sales (McCarty et al., 2010). The value of sales of the U.S. mushroom crop in 2014-2015 was $1.23 billion (USDA, 2015), a 62 percent increase since 1994-1995 (USDA, 1995).

Although there are over 1,000 types of mushrooms around the world, the U.S. commercial industry is dominated by white button mushrooms (Agaricus bisporus). They represent 90 percent of mushrooms consumed in the United States (Ren et al., 2008). The rest of the varieties include maitake, oyster, crimini, shiitake, beech, portabella, enoki, and wild mushrooms (such as morels, trufles, and chanterelles) (Mushroom Council). Shiitake and oyster, in particular, have gained more popularity over the past decade and account for 2 percent of the domestic mushrooms market (Lucier et al., 2003).

The mushrooms market consists of fresh mushrooms and processed mushrooms. Fresh mushroom sales represent 94 percent of total annual sales in 2014-2015 (USDA, 2015). During that year, the value of fresh sales of Agaricus mushrooms was $1.1 billion, compared to $65 million in processed sales (USDA, 2015).

The United States is the largest consumer of mushrooms in the world today (Dhar, 2014). Consumption is met largely by domestic production but also by a significant quantity of imports, especially of canned mushrooms (Dhar, 2014). According to the United States Department of Agriculture-Foreign Agricultural Service (USDA-FAS), the U.S. imported 50,687 metric tons (MT) of fresh mushrooms in 2015 compared to 22,095 MT in 2002. This represents a 129 percent increase. The share of imports in total consumption of fresh mushrooms has also increased dramatically since 1995. Imported fresh mushrooms accounted for 11 percent of fresh mushrooms consumption in 2015, increasing by 74.6 percent since 1995 (USDA, 2016). Canada is the largest exporter of fresh mushrooms to the U.S (McCarty et al., 2010). More recently, the share of total fresh mushroom imports has shifted from Canada to China and Korea (McCarty et al., 2010).

The share of imports of processed mushrooms in U.S. total consumption increased from 50.3 percent in 1995 to 78 percent in 2015. The bulk of processed mushrooms is canned, while frozen and dehydrated production account for smaller shares of the market (Lucier et al., 2003). China, India, Indonesia, and Netherlands have become the major suppliers of canned mushrooms to the U.S. market since 2003 (Dhar, 2014), accounting for 70 percent of total U.S. canned mushrooms import volume in 2015 (USDA-FAS, 2015).

Compared to meats, fruits, and vegetables, little is known about the demand structure of mushrooms in the U.S. Only four studies were found in the literature, such as a 2007 article by Adhikari et al. (2007), an unpublished study by Patterson and Richards (2003), an unpublished study by Patterson (2005), and a 2003 report by Lucier et al. (2003). The focus of Adhikari et al. (2007) is on the impact of low-carbohydrate information on demand for mushrooms, tomato, potato, broccoli, and lettuce. Patterson and Richards (2003) report short-run and long-run own-, cross-, and expenditure elasticities for white, portabella, other brown, shiitake, and other specialty mushrooms. Patterson (2005) conducts a series of simulations to examine the impacts of changes in market conditions, such as production, consumption, and equilibrium prices in the U.S. fresh mushroom market. Lucier et al. (2003) examined the distribution of fresh and processed mushrooms consumption.

The four aforementioned studies are quite dated and focus on the domestic market. Recognizing that the share of imports in total consumption has been increasing, and will likely continue to increase as U.S. consumers increasingly adopt healthier diets The goal of this thesis is to contribute to the understanding of mushroom demand in the U.S. by estimating import demand elasticities by sources. The elasticities should be of interest to food trade economists in general and countries exporting mushrooms to the U.S in particular.

1.2 Objectives and Methodology

The objective of this thesis is to 1) estimate U.S. import demand elasticities for fresh and canned mushrooms with data from January 2002 through December 2015 using source differentiated Almost Ideal Demand System (AIDS) and Rotterdam models, 2) use

two specification tests to determine which of the two models fits the data better, 3) estimate price and income elasticities of import demand for canned and fresh mushrooms from different sources, and 4) draw implications for exporting countries.

1.3 Organization of the Study

Chapter 2 provides an overview of the U.S. mushrooms market. Chapter 3 reviews the literature on mushroom markets. Chapter 4 lays out the source-differentiated AIDS and Rotterdam models and explains the specification tests. Chapter 5 presents the data, estimation procedure, and results. Chapter 6 summarizes and concludes.

CHAPTER 2： OVERVIEW OF U.S. MUSHROOMS MARKET

Mushrooms are one of the most difficult commodities to grow. They are grown on wooden or aluminum stacked beds, and are picked by hand (Chester County Pennsylvania). "It normally takes 14 to 16 weeks, from the beginning of the composting process to the final steaming off (sterilizing) of the growing house after harvest has ended, to complete one life cycle (crop) of mushrooms" (McCarty et al., 2010). As a result, highly technical operations and computerized systems are used by mushroom farms to monitor each point in the production process (Mushroom Farmers of Pennsylvania (MFPA)). Because of the difficulty in growing mushrooms, mushroom growers have focused more on the growing process at the expense of marketing their product (Wakchaure, 2011).

2.1 Production

The United States is the third largest mushrooms producer in the world, followed by China and Italy. Data from the Food and Agriculture Organization (FAO Statistics, 2014) show that global mushrooms production totaled 9.92 million MT in 2013, with China, Italy, and U.S., accounting for more than 80 percent of global production. The U.S. alone produced approximately 400,000 MT of mushrooms in 2013, accounting for 4.1 percent global production (FAO Statistics, 2014).

Mushrooms production in the U.S. is centered in Pennsylvania (USDA, 2015). The 68 mushroom farms in the state produce 63 percent of all U.S. white mushrooms valued at $554.4 million (MFPA). The second largest producing state is California, accounting for 11 percent of all U.S. white mushrooms (USDA, 2015).

With the improvement of advanced production technology and increasing demand of mushrooms in the U.S., the number of growers has increased. In 2015, the number of growers was 354, a 34 percent increase since 2000 (Figure 2.1).

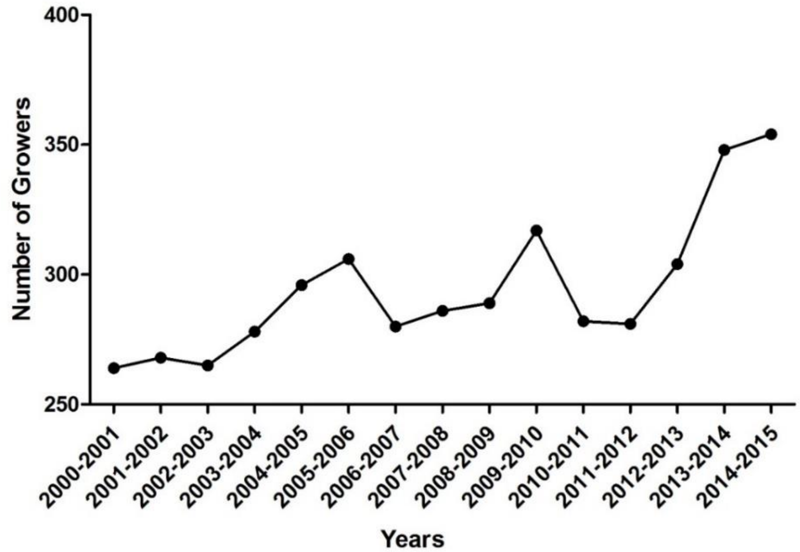

Figure 2.1. Number of mushroom growers in the U.S. (2000-2015)
Source: USDA, 2001 and 2015.

Figure 2.2 shows the evolution of mushroom production in the U.S. In 2015, 432,137 MT were produced, representing an increase of 21 percent since 1995. The share of fresh mushrooms in total production was 90 percent in 2015. That year, 390,951 MT of fresh mushrooms were produced, representing an increase of 58 percent since 1995. Production of processed mushrooms amounted to 41,186 MT, 62 percent below what it was in 1995, largely because of rising imports of processed mushrooms and decline in the number of growers for processing and mushrooms processors (McCarty et al., 2010).

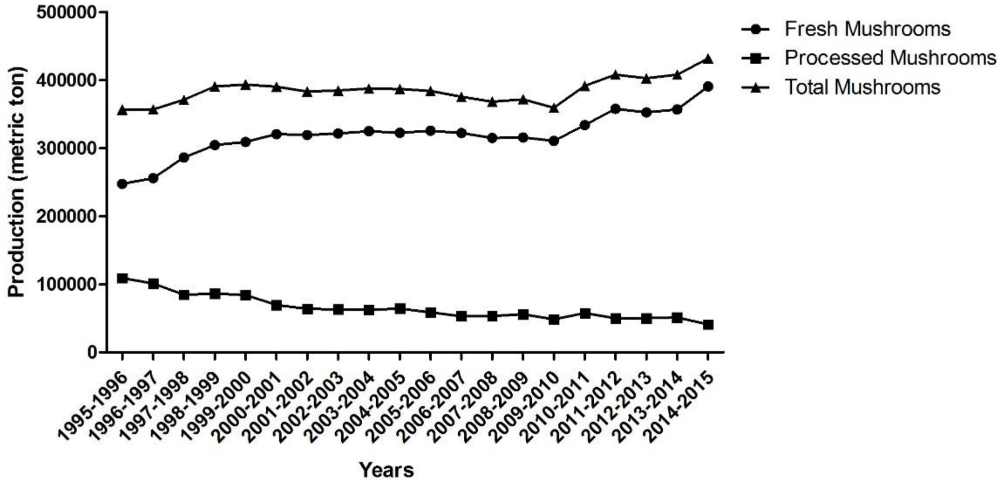

Figure 2.2. Mushroom production in the U.S. (1995-2015)
Sources: USDA, 2016.

The price of U.S. mushrooms is determined by several factors including the costs of raw materials, labor, harvesting, packing, marketing, transportation, energy to operate the growing house, cold storage rooms, and cannery (McCarty et al., 2010). For fresh mushrooms, since the process of production requires intensive labor in order to produce a consistent and high-quality crop (MFPA), the cost of labor accounts for a significant share of production costs (>25 percent) (McCarty et al., 2010). Market prices of fresh mushrooms indicate increased supply over the past several years. For instance, the season average price of fresh mushrooms has decreased 3.5 percent since 2009 (USDA, 2016), while the volume of fresh sales of mushrooms has increased 25 percent, from 304,272 MT in 2009 (USDA, 2010) to 381,174 MT in 2015 (USDA, 2015). The value of fresh sales of mushrooms increased 32 percent, from $82 million in 2009 (USDA, 2010) to $1 billion in 2015 (USDA, 2015). In contrast to fresh mushrooms, labor costs for processed mushrooms only account for a small share of total production costs (< 10 percent) (McCarty et al., 2010). The prices of cans and fuel costs have increased dramatically

since 2003 (McCarty et al., 2010). The season average price for processed mushrooms has increased 13 percent since 2009 (USDA, 2016), following a decrease in product availability for processing (McCarty et al., 2010). The value of processed sales of mushrooms has increased 4 percent since 2009 (USDA, 2010 and 2015).

2.2 Consumption

The evolution of consumption of mushrooms in the U.S. is shown in Figure 2.3. In 2015, consumption of fresh mushrooms (94 percent of all mushrooms consumption) was 431,049 MT, a 75 percent increase since 1995. In contrast, consumption of processed mushrooms declined from 211,115 MT in 1995 to 153,178 MT in 2015. This represents a 27 percent decrease because consumers have embraced fresh-market products (Lucier et al., 2003).

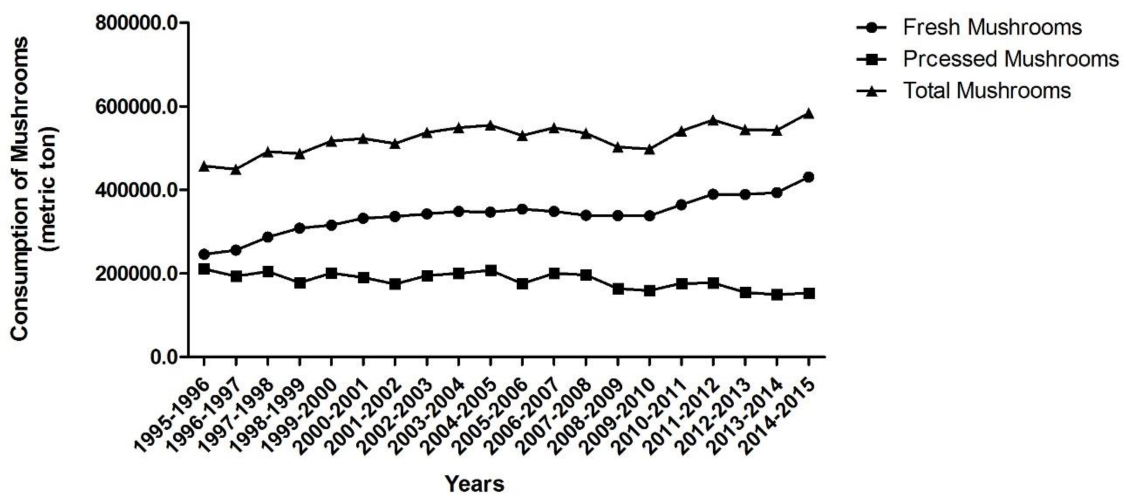

Figure 2.3. Mushroom consumption in the U.S. (1995-2015)
Source: USDA, 2016.

Numerous factors have been shown to contribute to mushroom consumption. According to surveys conducted by USDA, income is an important factor (Lucier et al., 2003). Consumers in the top income bracket reported the highest per capita consumption, while consumers in the lowest bracket reported the lowest (Lucier et al., 2003). The survey also indicates that half of all fresh mushrooms are consumed by 39 percent of the population whose incomes are more than 350 percent of the poverty level (Lucier et al., 2003). In addition to consumer income, prices also play an important role. Patterson and Richards (2003) reported price elasticities for several mushrooms, suggesting that mushrooms with high elasticities are affected strongly by price changes. For instance, price discounts from product promotions on most mushrooms lead to an increase in consumption (Patterson & Richards, 2003). Other factors including family size and rising public awareness of the positive effect on healthier diets may have also led to a rise in mushroom consumption (Lucier et al., 2003).

2.3 Trade

Imports of fresh mushrooms were 50,687 MT in 2015 compared to 22,095 metric tons in 2002 (USDA-FAS, 2015). This represents a 129 percent increase. The share of imports in total consumption for fresh mushrooms has also increased dramatically since 1995. Imported fresh mushrooms accounted for 11 percent of the fresh mushrooms consumption in 2015, increasing by 74.6 percent since 1995 (Figure 2.4). Although Canada is the largest trading partner for U.S. imports of fresh mushrooms, the share of total fresh mushrooms imports has shifted to China and Korea (McCarty et al., 2010).

The share of imports of processed mushrooms in U.S. total consumption increased from 50.3 percent in 1995 to 78 percent in 2015 (Figure 2.4). The bulk of

processed mushrooms is canned, while frozen and dehydrated production account for smaller shares of the market (Lucier et al., 2003). China, India, Indonesia, and Netherlands have become major suppliers of canned mushrooms to the U.S. market since 2003 (Dhar, 2014), accounting for 70 percent of total U.S. canned mushrooms import volume in 2015 (USDA-FAS, 2015).

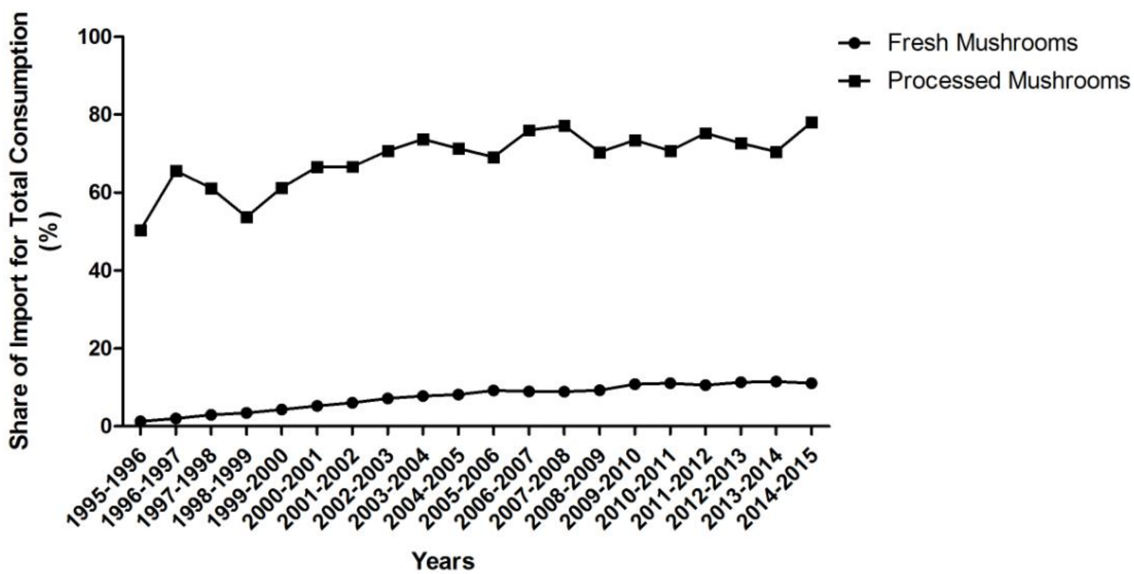

Figure 2.4. Share of mushroom imports in total consumption in the U.S. (1995-2015)
Source: USDA, 2016

Compared with imports, U.S. exports of fresh and processed mushrooms are small, accounting for 8,572 and 7,529 MT in 2015, respectively (USDA, 2016). Canada is the largest market for U.S. exports both of fresh and canned mushrooms. According to USDA (USDA-FAS, 2015), the volume of fresh mushrooms exported to Canada accounted for approximately 95 percent of total export in 2015, while the volume of canned mushrooms exported to Canada accounted for 52 percent of total export in 2015.

CHAPTER 3: LITERATURE REVIEW

The literature on the demand side of the mushroom market in the U.S. is limited. Lucier et al. (2003) examined the distribution of fresh and processed mushrooms consumption using data from USDA's Continuing Survey of Food Intakes by Individuals. Mushroom consumption per capita was greatest in the West and Midwest, and more than half of fresh mushrooms were purchased at retail and consumed at home. In contrast, three-fourths of processed mushrooms were consumed at home. Per capita mushroom use was highest among men and women aged 20-39, and lowest among children under 12. Consumers in the survey's top income bracket reported the highest per capita consumption, while consumers in the lowest bracket reported the lowest. Half of all fresh mushrooms were consumed by 39 percent of the population whose incomes were more than 350 percent of the poverty level.

Adhikari et al. (2007) examined the impacts of low carbohydrate information on the demand of mushrooms, tomato, potato, broccoli, and lettuce in the United States using an AIDS model. The information was found to play an important role in domestic demand across all the vegetables included in the study. The magnitudes of carbohydrate information elasticities were much smaller than the own-price and expenditure elasticities, although carbohydrate information emerged as a significant factor in vegetable demand. As expected, the signs of own-price elasticities were negative for all the vegetables, and the signs of expenditure elasticities were positive. The expenditure elasticity of mushroom was less than one (0.57). The own-price elasticity of mushrooms was -0.79. However, Adhikari et al. (2007) does not distinguish between fresh and processed mushrooms and between consumption from domestic and foreign sources.

In an unpublished study, Patterson and Richards (2003) report short-run and long-run own-, cross-, and expenditure elasticities for white, portabella, other brown, shiitake, and other specialty mushrooms. For fresh white mushrooms, the short-run own-price elasticity is -1.072 and the expenditure elasticity is 1.895. Again, no distinction was made between fresh and processed mushrooms. Import demand was not examined.

Another unpublished study by Patterson in 2005 conducts a series of simulations to examine the impacts of changes in market conditions, such as production, consumption, exports, imports, and equilibrium prices in the U.S. fresh mushroom market. Simulations show that both supply controls and increases in demand resulted in the increase of price, but only increases in demand led to an increase in grower revenue.

CHAPTER 4: MODEL SPECIFICATION AND SELECTION

4.1 Model Specification

The AIDS model, proposed by Deaton and Muellbauer in 1980, has been widely used by agricultural economists for estimating import demand (Alston et al., 1990; Henneberry & Hwang, 2007; Janda et al., 2000). The two major assumptions made when applying AIDS to import demand analysis are product aggregation across sources imports or block separability among goods (Yang & Koo, 1994). The implication of product aggregation is that the prices aggregated across import sources change together by the same proportion (Yang & Koo, 1994). This may not hold in the presence of quality differences (Yang & Koo, 1994) as would be the case in the mushroom import market. Mushroom importers may consider mushrooms imported from Canada differently from other countries due to quality differences (Johnson et al., 1979). Abstracting from quality differences, import prices may also differ because of transaction costs (Johnson et al., 1979). As for block separability among goods, the assumption is that the model consist only of expenditure share equations for one good from different sources (Yang & Koo, 1994). Again, such aggregation is inappropriate in the present case because there are two types of imported mushrooms (fresh and canned mushrooms) and demand of the two types of mushrooms shouldn't be treated as independent.

The Rotterdam model, developed by Barten in 1964 and Theil in 1965, has also been widely adopted in food import demand studies (Weatherspoon & Seale, 1995; Seale et al., 1992; Capps et al., 1994). The model is similar to the AIDS model in many respects, including a flexible functional form, identical data requirements, parsimony with respect to the numbers of parameters, and linearity in the parameters (Alston &

Chalfant, 1993). Both the Rotterdam and AIDS models are derived from classical consumer theory and, to ensure internal consistency, parametric restrictions are incorporated as prior information into estimation (Kastens & Brester, 1996).

4.1.1 A Source-Differentiated Almost Ideal Demand System (AIDS) Model

Following Yang and Koo (1994), the source-differentiated AIDS is given by

$$\omega_{ih\,t} = \alpha_{ih} + \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk} \ln(p_{jk\,t}) + \beta_{ih} \ln\left(\frac{X_t}{P_t^*}\right) \tag{1}$$

where α, β and γ are parameters. The subscripts i and j denote goods ($i, j = 1, \cdots, N$), and h and k denote origins, where the number of origins is not necessarily identical to the number of goods imported. For instance, good i may be imported from m different origins, while good j may have n origins (when $i \neq j$, $h = 1, \cdots, m,$ and $k = 1, \cdots, n$). At time t, the expenditure share of good i imported from source h is denoted by $\omega_{ih\,t}$, $p_{jk\,t}$ is the price of good j from source k, X_t is total expenditure on imports, and P_t^* is given by the price index:

$$\ln P_t^* = \alpha_0 + \sum_{i=1}^{N} \sum_{h=1}^{m} \alpha_{ih} \ln(p_{ih\,t}) + \frac{1}{2} \sum_{i=1}^{N} \sum_{h=1}^{m} \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk}^* \ln(p_{ih\,t}) \ln(p_{jk\,t}) \tag{2}$$

However, because the price index is nonlinear, causing estimation difficulties, the Stone index:

$$\ln P_t = \sum_{i=1}^{N} \sum_{h=1}^{m} \omega_{ih\,t} \ln(p_{ih\,t}) \tag{3}$$

is used as a linear approximation instead (Deaton & Muellbauer, 1980). Also, appearance $\omega_{ih\,t}$ as a variable in the Stone index leads to a simultaneity problem (Taljaard et al., 2003). To avoid the problem, Eales and Unnevehr (1988) suggest using

the lagged share $\omega_{ih\,t-1}$ in the Stone index. Substitution of the Stone index into equation (1), the share equations become:

$$\omega_{ih\,t} = \alpha_{ih} + \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk} \ln(p_{jk\,t}) + \beta_{ih}[\ln X_t - \ln P_t]$$
$$= \alpha_{ih} + \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk} \ln(p_{jk\,t}) + \beta_{ih}[\ln X_t - \sum_{i=1}^{N} \sum_{h=1}^{m} \omega_{ih\,t-1} \ln(p_{ih\,t})] \quad (4)$$

To ensure consistency with consumer theory, the following parametric restrictions are imposed:

Adding-up: $\sum_{i=1}^{N} \sum_{h=1}^{m} \alpha_{ih} = 1;\ \sum_{i=1}^{N} \sum_{h=1}^{m} \gamma_{ih\,jk} = 0;\ \sum_{i=1}^{N} \sum_{h=1}^{m} \beta_{ih} = 0;$

Homogeneity: $\sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk} = 0;$

Symmetry: $\gamma_{ih\,jk} = \gamma_{jk\,ih}$

Also, because n-1 of the equations can be estimated with any complete demand system, the parameter estimates for the remaining equations are obtained by using the adding-up restriction (Neudecker & Heijmans, 2012).

Because the data to be used is quarterly, as will be explained in the next section, quarterly dummy variables D_s are added to the share equations to capture time trends or seasonality (Chalfant, 1993), such that equation (4) becomes:

$$\omega_{ih\,t} = \alpha_{ih} + \sum_{s=1}^{3} \theta_{ih\,s} D_s + \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk}\, ln(p_{jk\,t}) \quad (5)$$
$$+\beta_{ih}[\ln X_t - \sum_{i=1}^{N} \sum_{h=1}^{m} \omega_{ih\,t-1} \ln(p_{ih\,t})]$$

The 4^{th} quarterly dummy variable is dropped in order to avoid the dummy variable trap.

The general expressions for the AIDS price and expenditure elasticities respectively are:

$$\eta^M_{ih\,jk} = -\delta_{ih\,jk} + \frac{\gamma_{ih\,jk}}{\omega_{ih}} - \beta_{ih}\left(\frac{\omega_{jk}}{\omega_{ih}}\right) \quad (6)$$

$$\epsilon_{ih} = 1 + \frac{\beta_{ih}}{\omega_{ih}} \quad (7)$$

where $\delta_{ih\,jk} = 1$ when $i = j$ and h $= k$, otherwise $-\delta_{ih\,jk}$=0 (Yang & Koo, 1994).

4.1.2 A Source-Differentiated Rotterdam Model

The source-differentiated Rotterdam model takes the form:

$$\overline{\omega}_{ih\,t}\,\Delta \ln q_{ih\,t} = \sum_{j=1}^{N}\sum_{k=1}^{n}\gamma_{ih\,jk}\,\Delta \ln\left(p_{jk\,t}\right) + \beta_{ih}[\Delta \ln X_t - \sum_{i=1}^{N}\sum_{h=1}^{m}\overline{\omega}_{ih\,t}\,\Delta \ln(p_{ih\,t})] \quad (8)$$

where $\overline{\omega}_{ih\,t}$ is the average import expenditure share weight between two time periods *t* and *t-1*. Δ is the first difference, and $q_{ih\,t}$ denotes the quantity of good imported at time *t*. Similar to the source-differentiated AIDS model, the subscripts *i* and *j* denote goods ($i, j = 1, \cdots, N$), and h and k denote origins, where the number of origins are not necessarily the same the number of goods imported. Since the dependent variable $\overline{\omega}_{ih\,t}$ also appears on the right hand side of the equation (8), it leads to a simultaneity problem. As in AIDS, the lagged average share $\overline{\omega}_{ih\,t-1}$ is used instead of the current share. Thus, equation (8) is rewritten as:

$$\overline{\omega}_{ih\,t}\,\Delta \ln q_{ih\,t} = \sum_{j=1}^{N}\sum_{k=1}^{n}\gamma_{ih\,jk}\,\Delta \ln\left(p_{jk\,t}\right) + \beta_{ih}[\Delta \ln X_t - \sum_{i=1}^{N}\sum_{h=1}^{m}\overline{\omega}_{ih\,t-1}\,\Delta \ln(p_{ih\,t})] \quad (9)$$

The adding-up, homogeneity, and symmetry restrictions for the Rotterdam parameters are given by:

Adding-up: $\sum_{i=1}^{N} \sum_{h=1}^{m} \gamma_{ih\,jk} = 0; \;\; \sum_{i=1}^{N} \sum_{h=1}^{m} \beta_{ih} = 1;$

Homogeneity: $\sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk} = 0;$

Symmetry: $\gamma_{ih\,jk} = \gamma_{jk\,ih}$

Appending the quarterly dummies D_s to account for possible time trends or seasonality, the source-differentiated Rotterdam model is re-written as:

$$\bar{\omega}_{ih\,t} \Delta \ln q_{ih\,t} = \alpha_{ih} + \sum_{s=1}^{3} \theta_{ih\,s} D_s + \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk} \Delta \ln\left(p_{jk\,t}\right)$$
$$+\beta_{ih}[\Delta \ln X_t - \sum_{i=1}^{N} \sum_{h=1}^{m} \bar{\omega}_{ih\,t-1} \Delta \ln(p_{ih\,t})] \quad (10)$$

The expressions for the price and expenditure elasticities respectively are:

$$\eta_{ih\,jk}^{M} = \frac{\gamma_{ih\,jk} - \beta_{ih}\,\omega_{jk}}{\omega_{ih}} \quad (11)$$

$$\epsilon_{ih} = \frac{\beta_{ih}}{\omega_{ih}} \quad (12)$$

4.2 Model Selection

Since the source-differentiated AIDS and Rotterdam models may lead to different parameter estimates, and the estimates may affect the point estimates as well as the statistical significance of the elasticities for fresh and canned mushrooms, a test is needed to choose between the two demand systems. The two specification tests suggested by Alston and Chalfant (1993) are implemented to determine which model fits the import data better.

The starting point of the specification tests is to note that, in a time series context, the source-differentiated AIDS model has a close relationship to the source-differentiated

Rotterdam model. To see why, consider the first-differenced version of the source-differentiated AIDS model (equation 1):

$$\Delta\omega_{ih\,t} = \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk}\, \Delta\ln\left(p_{jk\,t}\right) + \beta_{ih}[\Delta \ln X_t - \Delta\ln P_t^*] \tag{13}$$

where $\Delta\ln P_t^*$ is replaced by the first difference of Stone's index $\Delta[\sum_{i=1}^{N} \sum_{h=1}^{m} \omega_{ih\,t} \ln(p_{ih\,t})]$, or its approximation $\sum_{i=1}^{N} \sum_{h=1}^{m} \omega_{ih\,t}\, \Delta\ln(p_{ih\,t})$ (Deaton & Muellbauer, 1980). Substitution of the Stone index (equation 3) into equation (13) and using the lagged share to avoid the simultaneity problem yields:

$$\Delta\omega_{ih\,t} \approx \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk}\, \Delta\ln\left(p_{jk\,t}\right) + \beta_{ih}[\Delta \ln X_t - \sum_{i=1}^{N} \sum_{h=1}^{m} \omega_{ih\,t-1}\, \Delta\ln(p_{ih\,t})] \tag{14}$$

Although first-differencing eliminated the intercept, α_{ih}, the conventional practice in the literature is to introduce dummy variables D_s and intercepts to account for seasonality and time trend (Alston & Chalfant, 1993), resulting in:

$$\Delta\omega_{ih\,t} = \alpha_{ih} + \sum_{s=1}^{3} \theta_{ih\,s}\, D_s + \sum_{j=1}^{N} \sum_{k=1}^{n} \gamma_{ih\,jk}\, \Delta ln\left(p_{jk\,t}\right) + \beta_{ih}[\Delta\ln X_t - \sum_{i=1}^{N} \sum_{h=1}^{m} \omega_{ih\,t-1}\, \Delta\ln(p_{ih\,t})] \tag{15}$$

It is easy to see that the right hand side of the first-differenced version of source-differentiated AIDS is virtually identical to the right hand side of the source-differentiated Rotterdam model (equation 10). The two models' respective dependent variables, however, are different making it difficult to decide which of the two models fit the data best using standard measures of fit (Alston & Chalfant, 1993). To compare the two models with different dependent variables, Alston and Chalfant (1993) developed two specification tests which are discussed in the next two sections.

4.2.1 Testing the AIDS Specification

The source-differentiated AIDS specification can be tested using the following compound model:

$$(1-h)\Delta\omega_{ih\,t} + h\,\bar{\omega}_{ih\,t}\Delta\ln q_{ih\,t} = \alpha_{ih} + \sum_{s=1}^{3}\theta_{ih\,s}\,D_s + \sum_{j=1}^{N}\sum_{k=1}^{n}\gamma_{ih\,jk}\,\Delta ln\big(p_{jk\,t}\big) + \beta_{ih}[\Delta\ln X_t - \sum_{i=1}^{N}\sum_{h=1}^{m}\omega_{ih\,t-1}\,\Delta\ln(p_{ih\,t})] \quad (16)$$

Equation (16) is a linear combination of the first-differenced version of source-differentiated AIDS model and source-differentiated Rotterdam model. If $h = 0$, equation (16) reduces to equation (15), implying that first-differenced version of source-differentiated AIDS model is correct. If $h = 1$, then equation (16) reduces to an approximation of, not an exact representation of, the source-differentiated Rotterdam model because the last portion of the equation is contributed to lagged share $\omega_{ih\,t-1}$, instead of lagged average share $\bar{\omega}_{ih\,t-1}$. Since it is not exactly the source-differentiated Rotterdam model, finding $h = 1$ would be evidence against the first-differenced version of source-differentiated AIDS model in favor of the source-differentiated Rotterdam model (Alston & Chalfant, 1993).

4.2.2 Testing the Rotterdam Specification

The source-differentiated Rotterdam model can be tested in the alternative compound model as:

$$(1-t)\bar{\omega}_{ih\,t}\Delta\ln q_{ih\,t} + t\,\Delta\omega_{ih\,t} = \alpha_{ih} + \sum_{s=1}^{3}\theta_{ih\,s}\,D_s + \sum_{j=1}^{N}\sum_{k=1}^{n}\gamma_{ih\,jk}\,\Delta\ln\big(p_{jk\,t}\big) + \beta_{ih}[\Delta\ln X_t - \sum_{i=1}^{N}\sum_{h=1}^{m}\bar{\omega}_{ih\,t-1}\,\Delta\ln(p_{ih\,t})] \quad (17)$$

A test of the hypothesis that $t = 0$ can be interpreted as a test of the hypothesis that the source-differentiated Rotterdam model is correct. If $t = 1$, then equation (17) reduces to an approximation of the first-differenced version of source-differentiated AIDS model because the last portion of the equation (17) contains the lagged average share $\overline{\omega}_{ih\,t-1}$, instead of the lagged share $\omega_{ih\,t-1}$. Since it is not exactly the first-differenced version of source-differentiated AIDS model, $t = 1$ is evidence against the source-differentiated Rotterdam model in the direction of the first-differenced version of source-differentiated AIDS model (Alston & Chalfant, 1993). The data requirements for estimating the two models and selecting between them are the same. One needs expenditure shares and prices by commodity and by source. The next section discusses mushroom data used to estimate both models.

CHAPTER 5: DATA, ESTIMATION PROCEDURE, AND RESULTS

5.1 Data

U.S. mushrooms imports are categorized into fresh mushrooms and canned mushrooms. Table 1 lists the Harmonized Tariff Schedule (HTS) numbers and the corresponding definitions for imported fresh and canned mushrooms. According to McCarty et al. (2010), fresh mushrooms are represented by HTS numbers 0709.51.0100, 0709.59.0000, and 0709.59.9000; and canned mushrooms by 2003.10.0127, 2003.10.0143, 2003.10.0131, 2003.10.0147, 2003.10.0137, and 2003.10.0153. The dataset used to estimate the source-differentiated AIDS and Rotterdam models consists of quarterly time series of aggregated fresh and canned mushroom quantities (in 1000's of kilograms (kg)) and prices (unit values) from the first quarter of 2002 until the fourth quarter of 2015. The source of the data is the USDA Foreign Agricultural Service (USDA-FAS, 2015).

Table 2 provide summary statistics for import expenditure shares for fresh and canned mushrooms during the sample period. Canned mushrooms account for 52 percent of total U.S. mushrooms import on average, and fresh mushrooms account for the rest.

Fresh and canned mushrooms are imported from different sources. Canada is the largest exporter to the U.S, accounting for 86 percent of U.S. fresh mushroom imports, followed by Mexico (6 percent), China (4 percent), and South Korea (2 percent). Because imports from individual other countries are small (< 2 percent), they are combined into

"rest of the world (ROW)" to save degrees of freedom (Yang & Koo, 1994). Although Canada is the largest exporter, the import expenditure share of fresh mushroom imports shifted from Canada to Mexico, China, and South Korea.

Figure 5.1 plots the import shares of fresh mushrooms expenditures from the different sources. Canadian fresh mushrooms accounted for 76.12 percent of U.S. fresh mushroom imports in 2015, declining by 17 percent since 2002 largely because Canadians consumed a larger share of production (McCarty et al., 2010). The import share of fresh mushrooms from Mexico, China and South Korea increased by 560, 263, and 136 percent since 2002, respectively.

China is the largest exporter of canned mushrooms to the U.S., accounting for 41 percent of U.S. canned mushrooms imports. The other sources are Indonesia (16 percent), India (15 percent), and Netherlands (13 percent). Imports of canned mushrooms from other countries that are smaller than 10 percent were combined into ROW. Figure 5.2 plots the import expenditure shares of canned mushrooms from different sources including China, India, Indonesia, Netherlands, and ROW. Although China is the largest exporter on average, the import share of canned mushrooms expenditure from China dropped after 2011. In 2011, the Chinese Inspection and Quarantine Services stopped exports of canned mushrooms to the U.S. because of pesticide contamination (Mushroom Business). The halt of exports of canned mushrooms is still in effect as of this writing. U.S. imports of canned mushrooms from India also declined since 2012 due to pesticide contamination (Schreiber Food International). As a result, imports from the Netherlands increased. (Mushroom Business).

Table 1

HTS numbers and definitions for fresh and canned mushrooms.

	HTS number	Definition
Fresh Mushrooms	709510100	Mushrooms of the genus Agaricus
	709590000 [a]	Other mushrooms
	709599000 [b]	Other mushrooms
Canned Mushrooms	2003100127	Mushrooms of the genus Agaricus in containers each holding NOT more than 255g-Whole(including buttons)
	2003100143	Mushrooms of the genus Agaricus in containers each holding more than 255g-Whole(including buttons)
	2003100131	Mushrooms of the genus Agaricus in containers each holding NOT more than 255g-Sliced
	2003100147	Mushrooms of the genus Agaricus in containers each holding more than 255g-Sliced
	2003100137	Mushrooms of the genus Agaricus in containers each holding NOT more than 255g-Other
	2003100153	Mushrooms of the genus Agaricus in containers each holding more than 255g-Other

Notes: [a b] HTS number 709590000 and 709599000 are the same category. Before 2007, the United States International Trade Commission used HTS number 709590000 to represent other mushrooms. After 2007, the Commission use HTS number 709599000 to represent other mushrooms. Source: United States International Trade Commission.

Table 2

Summary statistics for expenditure shares of U.S. mushrooms imports.

Variables	Mean	Std. Dev	Maximum	Minimum
Fresh mushrooms	0.4805	0.0961	0.6401	0.2887
Canada	0.4113	0.0749	0.5447	0.2387
China	0.0199	0.0099	0.0407	0.0058
Mexico	0.0282	0.0170	0.0775	0.0052
South Korea	0.0099	0.0095	0.0467	0.0001
ROW	0.0112	0.0057	0.0256	0.0013
Canned mushrooms	0.5195	0.0961	0.7113	0.3599
China	0.2135	0.1280	0.4480	0.0036
India	0.0782	0.0554	0.1752	0.0000
Indonesia	0.0838	0.0406	0.1548	0.0292
Netherlands	0.0651	0.0757	0.2310	0.0014
ROW	0.0789	0.0437	0.1628	0.0160

Source: USDA Foreign Agricultural Service.

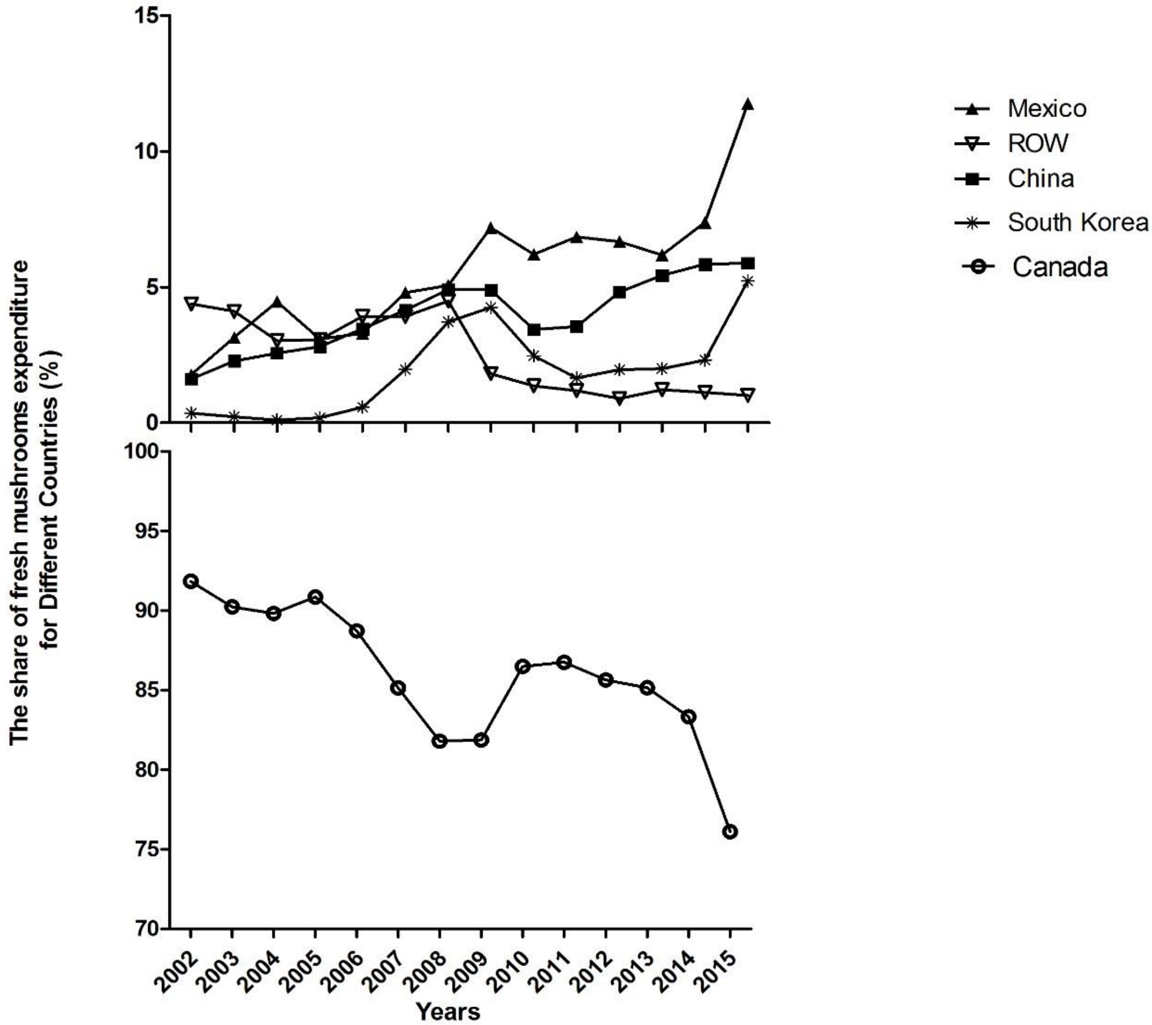

Figure 5.1 Percentage of U.S. fresh mushrooms imports from different sources (2002-2015).

Source: USDA Foreign Agricultural Service.

Note: the scales are different for Canada and other counties.

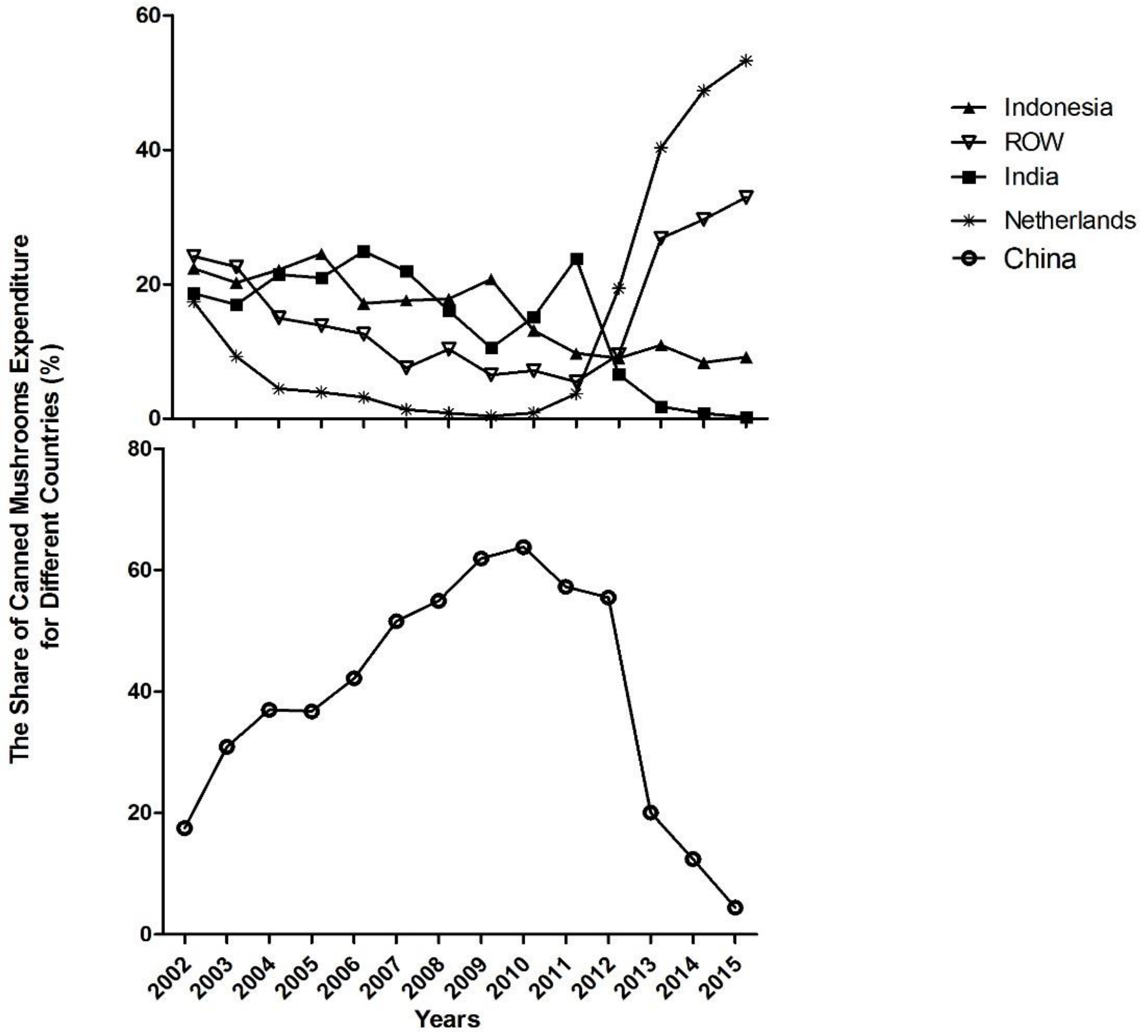

Figure 5.2 Percentage of U.S. canned mushrooms imports from different sources (2002-2015).

Source: USDA Foreign Agricultural Service.

Note: the scales are different for China and other counties.

Table 3 provides summary statistics of unit values (dollar value/quantity of imports), a proxy for prices per kilogram, of fresh and canned mushrooms. The price of fresh mushrooms on average ($3.0416) was almost a dollar higher than the price of canned mushrooms ($2.1629).

For fresh mushrooms, the import price of the Chinese fresh mushrooms ($0.8979) is the lowest on average, followed by South Korea's ($1.3717), Mexico ($2.3616), Canada ($3.2158), and ROW ($7.3611). The highest import price of fresh mushroom, $14.3925, belongs to South Africa.

For canned mushrooms, the import price of Indian canned mushrooms ($1.6942) is the lowest, followed by ROW ($2.0198), China ($2.1382), Netherlands ($2.3458), and Indonesia ($2.6164). China and India, the principal exporters of canned mushrooms to the U.S. market before 2011, were very successful selling lower priced canned mushrooms to the U.S. market before 2011 (McCarty et al., 2010).

Table 3

Summary statistics for prices of U.S. mushrooms imports.

Variables	Mean	Std. Dev	Maximum	Minimum
Fresh mushrooms	3.0416	2.7372	14.3925	0.4412
Canada	3.2158	0.3941	3.9657	2.5021
China	0.8979	0.1794	1.4643	0.6859
Mexico	2.3616	0.3708	3.1162	1.6971
South Korea	1.3717	1.3390	10.0000	0.4412
ROW	7.3611	2.9786	14.3925	2.4029
Canned mushrooms	2.1629	0.5894	3.6332	0.6121
China	2.1382	0.5524	3.2568	1.3634
India	1.6833	0.4916	2.5970	0.0000
Indonesia	2.6164	0.5601	3.6332	1.9185
Netherlands	2.3458	0.5213	3.4512	1.5608
ROW	2.0198	0.4146	2.8976	1.4647

Source: USDA Foreign Agricultural Service.

5.2 Estimation Procedure

The econometric procedure used to estimate the demand models (equation 5, 10, and 15) is the seemingly unrelated regression (SUR) with correction for first-order serial correlation as described in the SAS PROC MODEL (SAS Institute Inc, 2000). Quarterly dummy variables and intercepts were appended to the expenditure share equations to capture time trends or seasonality. To account for the effect of pesticide contamination in China and India on imports, a dummy variable taking a value of 1 after 2011 and zero otherwise was added to the expenditure share equations of fresh and canned mushrooms from all sources.

5.3 Results

5.3.1 Elasticity Estimates

The own-, cross-price elasticities and expenditure elasticities and their respective standard errors were calculated using the Estimate statement in SAS. Formulas 6 and 7 are used for the source-differentiated AIDS model and formulas 11 and 12 for the source-differentiated Rotterdam model.

Aside from those not different from zero, the expenditure elasticities, reported in Table 4, exhibit some similarities between the two models. For instance, the expenditure elasticities of Canadian fresh mushroom are statistically significant in both models. The expenditure elasticities of Chinese canned mushrooms are also statistically significant in both models and considerably larger than one, suggesting that when import expenditures rise, a large portion of them are spent on Chinese canned mushrooms. However, differences are also observed between the two models. The expenditure elasticity of

canned mushrooms imported from ROW is statistically significant in the source-differentiated Rotterdam model, while it is not statistically significant in the source-differentiated AIDS model.

The source-differentiated AIDS and Rotterdam models also differ in estimates of price elasticities but the bulk of the price elasticities are not statistically different from zero in both models. The matrices of price elasticities obtained from the source-differentiated AIDS and Rotterdam models using equations (6) and equation (11), respectively are presented in Table 5a for fresh mushrooms and 5b for canned mushrooms. Elasticities associated with ROW are shown for completeness but are not discussed in conjunction with the elasticities for specific countries.

As expected, most of the own-price elasticities estimated from the two models are negative. However, the own-price elasticity for Chinese fresh mushrooms (Table 5a) and Indian canned mushrooms (Table 5b) are positive, but not statistically significant in the source-differentiated AIDS model. In the source-differentiated Rotterdam model, the own-price elasticity for Indian and Dutch canned mushrooms are positive but not statistically significant (Table 5b).

The own-price elasticities estimated from the two models exhibit some similarities. For instance, the own-price elasticities for Canadian and Mexican fresh mushrooms (Table 5a) and for Chinese canned mushrooms (Table 5b) are statistically significant in the both models. However, differences are also observed between the two models. For fresh mushrooms (Table 5a), the own-price elasticity for fresh mushrooms imported from South Korea is statistically significant in the source-differentiated AIDS model, but is not statistically significant in the source-differentiated Rotterdam model.

Table 4

Estimated expenditure elasticities: source-differentiated AIDS and Rotterdam models.

	Source-differentiated AIDS model	Source-differentiated Rotterdam model
Fresh From:		
Canada	0.250**	0.188**
	(0.099)	(0.076)
China	-0.273	-0.412
	(0.530)	(0.422)
Mexico	0.226	0.137
	(0.345)	(0.236)
South Korea	-0.215	-0.264
	(0.570)	(0.459)
ROW	0.529	0.466
	(0.542)	(0.484)
Canned From:		
China	3.595***	2.657***
	(0.335)	(0.343)
India	-0.036	0.061
	(0.569)	(0.468)
Indonesia	0.293	0.246
	(0.282)	(0.209)
Netherlands	0.603	0.266
	(0.611)	(0.514)
ROW	0.810	3.987***
	(0.501)	(0.675)

Notes: ROW: the rest of the world; the numbers in parentheses right underneath the elasticity are standard errors. Single, double, and triple asterisks (*) represent significance at 10 percent, 5 percent, 1 percent levels, respectively.

With respect to cross-price elasticities, results are also different between the two models. In Table 5a, the cross-price elasticities of substitution between Chinese canned mushrooms and Canadian fresh mushrooms are statistically significant in the source-differentiated Rotterdam model, but are not statistically significant in the source-differentiated AIDS model. The cross-price elasticities of demand between Indian canned mushrooms and Canadian fresh mushrooms are statistically significant in the source-differentiated AIDS model, but are not statistically significant in the source-differentiated Rotterdam model.

In Table 5b, the cross-price elasticities of demand between Chinese fresh mushrooms and Chinese canned mushrooms are statistically significant in the source-differentiated AIDS model, but are not statistically significant in the source-differentiated Rotterdam model. The cross-price elasticities of demand between South Korea’s fresh mushrooms and Chinese canned mushrooms are statistically significant in the source-differentiated Rotterdam model, but are not statistically significant in the source-differentiated AIDS model.

In general, since most of the elasticities are not statistically different from zero between the two models, the elasticities exhibit some similarities, but minor differences are also observed between the two models.

Table 5a

Estimated price elasticities of demand for fresh mushrooms: source-differentiated AIDS and Rotterdam models.

	Fresh From:									
	Canada		China		Mexico		South Korea		ROW	
	A	R	A	R	A	R	A	R	A	R
Canada	-0.526***	-0.475***	-0.009	-0.011	0.073**	0.122***	0.006	-0.005	-0.038*	-0.041**
	(0.152)	(0.163)	(0.042)	(0.040)	(0.036)	(0.037)	(0.012)	(0.012)	(0.019)	(0.018)
China	0.033	0.029	0.550	-0.191	-0.245	0.243	0.040	0.045	0.073	0.257
	(0.823)	(0.811)	(0.487)	(0.521)	(0.335)	(0.336)	(0.076)	(0.103)	(0.142)	(0.172)
Mexico	1.080**	1.809***	-0.183	0.161	-1.551***	-2.058***	0.030	0.060	-0.013	0.018
	(0.503)	(0.515)	(0.237)	(0.236)	(0.279)	(0.270)	(0.050)	(0.042)	(0.084)	(0.077)
South Korea	0.437	-0.030	0.080	0.086	0.098	0.180	-0.961***	-0.027	0.017	0.042
	(0.513)	(0.492)	(0.151)	(0.204)	(0.141)	(0.119)	(0.086)	(0.100)	(0.081)	(0.114)
ROW	-1.499**	-1.640**	0.115	0.440	-0.040	0.036	0.008	0.030	-1.477***	-1.022 ***
	(0.665)	(0.677)	(0.251)	(0.307)	(0.210)	(0.194)	(0.072)	(0.102)	(0.165)	(0.226)

	Canned From:									
	China		India		Indonesia		Netherlands		ROW	
	A	R	A	R	A	R	A	R	A	R
Canada	0.154	0.203**	-0.123**	-0.087	-0.003	0.003	0.127*	0.047	0.088***	0.057**
	(0.097)	(0.094)	(0.056)	(0.059)	(0.103)	(0.097)	(0.063)	(0.057)	(0.008)	(0.006)
China	-0.729	-0.576	0.108	0.304	0.657	0.693	-0.200	-0.180	-0.015	-0.211***
	(0.536)	(0.634)	(0.338)	(0.340)	(0.761)	(0.754)	(0.364)	(0.510)	(0.042)	(0.033)
Mexico	-0.090	-0.449	0.460**	0.783***	-0.117	-0.434	0.087	-0.112	0.071**	0.085***
	(0.347)	(0.301)	(0.220)	(0.205)	(0.486)	(0.480)	(0.227)	(0.189)	(0.027)	(0.019)
South Korea	-0.091	-0.691	0.652*	0.254	0.351	0.327	0.036	-0.325	-0.405***	0.447***
	(0.511)	(0.550)	(0.343)	(0.384)	(0.337)	(0.322)	(0.341)	(0.377)	(0.045)	(0.036)
ROW	2.051***	1.745**	-0.934**	-0.354	0.648	0.453	-0.439	-0.533	1.039***	0.379***
	(0.566)	(0.689)	(0.354)	(0.457)	(0.545)	(0.512)	(0.361)	(0.528)	(0.043)	(0.038)

Notes: ROW: the rest of the world; A: source-differentiated AIDS model; R: source-differentiated Rotterdam model. The numbers in parentheses right underneath the elasticity are standard errors. Single, double, and triple asterisks (*) represent significance at 10 percent, 5 percent, 1 percent levels, respectively.

Table 5b

Estimated price elasticities of demand for canned mushrooms: source-differentiated AIDS and Rotterdam models.

	Canned From:									
	China		India		Indonesia		Netherlands		ROW	
	A	R	A	R	A	R	A	R	A	R
China	-1.302***	-1.032**	-0.199	-0.253	-0.277**	-0.301**	-0.252	-0.224	-0.267***	0.018
	(0.319)	(0.419)	(0.169)	(0.201)	(0.122)	(0.114)	(0.162)	(0.176)	(0.026)	(0.027)
India	0.233	-0.136	0.077	0.554*	0.256	-0.060	-0.396	-0.087	0.243***	-0.261***
	(0.421)	(0.508)	(0.368)	(0.441)	(0.198)	(0.201)	(0.269)	(0.300)	(0.045)	(0.037)
Indonesia	-0.001	-0.252	0.213	-0.070	-0.702	-0.217	-0.020	0.036	0.023***	0.167***
	(0.282)	(0.267)	(0.179)	(0.186)	(0.549)	(0.525)	(0.188)	(0.176)	(0.022)	(0.017)
Netherlands	-0.186	-0.226	-0.525	-0.121	-0.052	0.044	-0.747*	0.177	0.381***	-0.142***
	(0.476)	(0.537)	(0.317)	(0.362)	(0.245)	(0.229)	(0.427)	(0.456)	(0.048)	(0.041)
ROW	-0.128	-0.235	0.175***	-0.566***	-0.019	-0.136**	0.301***	-0.360***	-1.432***	-1.231***
	(0.107)	(0.144)	(0.039)	(0.053)	(0.042)	(0.057)	(0.033)	(0.044)	(0.040)	(0.053)
	Fresh From:									
	Canada		China		Mexico		South Korea		ROW	
	A	R	A	R	A	R	A	R	A	R
China	-1.078***	-0.625**	-0.145***	-0.115*	-0.107**	-0.130***	-0.042*	-0.061**	0.073**	0.067*
	(0.236)	(0.232)	(0.052)	(0.062)	(0.048)	(0.042)	(0.025)	(0.027)	(0.032)	(0.038)
India	-0.526	-0.406	0.023	0.068	0.173**	0.284***	0.081*	0.029	-0.127**	-0.046
	(0.364)	(0.356)	(0.085)	(0.101)	(0.079)	(0.073)	(0.043)	(0.049)	(0.050)	(0.065)
Indonesia	-0.035	-0.009	0.145	0.151	-0.041	-0.149	0.037	0.034	0.089	0.063
	(0.471)	(0.460)	(0.178)	(0.178)	(0.161)	(0.161)	(0.039)	(0.038)	(0.072)	(0.068)
Netherlands	0.657	0.266	-0.079	-0.068	0.027	-0.052	-0.003	-0.055	-0.076	-0.089
	(0.433)	(0.396)	(0.108)	(0.155)	(0.097)	(0.057)	(0.051)	(0.057)	(0.061)	(0.090)
ROW	0.228	-1.268***	-0.025**	-0.141***	0.009	-0.078***	-0.061***	0.014**	0.144***	-0.014*
	(0.206)	(0.278)	(0.010)	(0.013)	(0.014)	(0.019)	(0.005)	(0.007)	(0.006)	(0.008)

Notes: ROW: the rest of the world; A: source-differentiated AIDS model; R: source-differentiated Rotterdam model. The numbers in parentheses right underneath the elasticity are standard errors. Single, double, and triple asterisks (*) represent significance at 10 percent, 5 percent, 1 percent levels, respectively.

5.3.2 Specification Tests and Model Selection

The analysis above shows that the results obtained from the source-differentiated AIDS model do differ from that from the source-differentiated Rotterdam model. The question is which model is the true model.

To address that question, two specification tests are conducted. The first specification test examines the validity of the first-differenced version of source-differentiated AIDS model by estimating equation (16) and testing the null hypothesis that $h = 0$. The test can be interpreted as a test of the hypothesis that the first-differenced version of source-differentiated AIDS model is correct. In Table 6, the estimated value of h is -0.00638 and is not significantly different from zero (p-value= 0.9539). Thus, one cannot reject the null hypothesis that $h = 0$ and the first-differenced version of source-differentiated AIDS model is the preferred specification.

The second test examines the validity of the source-differentiated Rotterdam model by estimating equation (17) and testing the null hypothesis that $t = 0$, i.e., that the source-differentiated Rotterdam model is correct. In Table 6, the estimated value of t is 1.048618 and is significantly different from zero at 1 percent level (p-value<.0001). Thus, one rejects the null hypothesis that $t = 0$, and concludes that the source-differentiated Rotterdam model is not correct for this data set and the first-differenced version of source-differentiated AIDS model is (statistically) more appropriate.

Table 6
Testing the AIDS and Rotterdam specifications.

Parameter	Estimate	Approx Std Err	Approx Pr > |t|
h	-0.00638	0.1098	0.9539
t	1.048618	0.0544	<.0001

Based on the results of two specification tests above, the first-differenced version of source-differentiated AIDS model is selected in favor of the source-differentiated Rotterdam model to represent the U.S. import demand of mushrooms. The next step is to choose between the un-differenced with the first-differenced (equation 5 compared to 15) version of the source-differentiated AIDS model to see which of the two is a better representation of U.S. mushroom import demand.

Table 7 presents the expenditure elasticities estimated from the two models. These elasticities exhibit some similarities. For instance, the expenditure elasticities of Chinese canned mushrooms are greater than 1 and are statistically significant at 1 percent level in both models; the expenditure elasticities of Canadian fresh mushrooms are lower than 1 and are statistically significant at 5 percent level in both models. However, minor differences are also observed between the two models. For instance, the expenditure elasticities for canned mushrooms imported from ROW are statistically significant in the first-differenced version of source-differentiated AIDS model but not statistically significant in the un-differenced version of source-differentiated AIDS model.

Table 7

Estimated expenditure elasticities: source-differentiated AIDS model and First-differenced version of source-differentiated AIDS model.

	Source-differentiated AIDS model	First-differenced version of source-differentiated AIDS model
Fresh From:		
Canada	0.250**	0.215**
	(0.099)	(0.085)
China	-0.273	-0.197
	(0.530)	(0.406)
Mexico	0.226	0.082
	(0.345)	(0.262)
South Korea	-0.215	-0.432
	(0.570)	(0.578)
ROW	0.529	0.715
	(0.542)	(0.587)
Canned From:		
China	3.595***	3.596***
	(0.335)	(0.305)
India	-0.036	-0.384
	(0.569)	(0.582)
Indonesia	0.293	0.333
	(0.282)	(0.262)
Netherlands	0.603	1.092*
	(0.611)	(0.549)
ROW	0.810	0.919***
	(0.501)	(0.339)

Notes: Refer to table 4 footnote.

The matrices of price elasticities estimated from both models are reported in Table 8a for fresh mushrooms and 8b for canned mushrooms.

The own-price elasticities for fresh mushrooms estimated from two models are all negative except for China where the elasticity is insignificantly positive in the un-differenced AIDS model (Table 8a). The own-price elasticities for canned mushrooms are all negative except those associated with imports from India (Table 8b), but are not statistically significant in both models.

The own-price elasticities estimated from the two models are similar. For instance, the own-price elasticities for Canadian, Mexican, and South Korea's fresh mushrooms (Table 8a) and Chinese canned mushrooms (Table 8b) are all statistically significant in the both models. The own-price elasticities for Chinese fresh mushrooms (Table 8a), Indian and Indonesian canned mushrooms (Table 8b) are all not statistically significant in the both models. All of these significant own-price elasticities estimated from the two models are similarly elastic or inelastic. For instance, in both models, the own-price elasticities for Mexican fresh mushrooms (Table 8a) and Chinese canned mushrooms (Table 8b) are price elastic, Canadian and South Korea's fresh mushrooms are price inelastic (Table 8a). However, minor differences are also observed between the two models. For instance, the own-price elasticities for Dutch canned mushrooms are statistically significant in the first-differenced version of source-differentiated AIDS model, but are not statistically significant in the un-differenced version of source-differentiated AIDS model.

The cross-price elasticities from the two models are also similar. In Table 8a, the cross-price elasticities of demand between Canadian and Mexican fresh mushrooms,

between Indian canned mushrooms and Canadian fresh mushrooms and between Indian canned mushrooms and Mexican fresh mushrooms are statistically significant in both models. In Table 8b, the cross-price elasticities of demand between Indonesian and Chinese canned mushrooms, between Canadian fresh mushrooms and Chinese canned mushrooms, between Chinese fresh mushrooms and Chinese canned mushrooms, between Mexican fresh mushrooms and Chinese canned mushrooms and between Mexican fresh mushrooms and Indian canned mushrooms are statistically significant in both models.

In general, the elasticities obtained from the two models exhibit some similarities, but minor differences are also observed between the two models. Except the elasticities of ROW, the number of price and income elasticities that are significant at five or one percent level in the first-differenced version of source-differentiated AIDS model is higher than that in the AIDS in levels. For instance, 16 out of 72 elasticities are significantly different from zero at five or one percent level in the first-differenced version of source-differentiated AIDS model, while 15 out of 72 significant elasticities are in the un-differenced version of source-differentiated AIDS model. Hence, judging by the frequency of statistically significant elasticities alone, it seems that the first-differenced of the source-differentiated AIDS model performs better than the un-differenced version of the source-differentiated AIDS model.

Furthermore, there are two positive own-price elasticities in the un-differenced AIDS model, while only one positive own-price elasticities in the first-differenced version of source-differentiated AIDS model (although all of the positive own-price elasticities are not statistically significant). Hence, judging by the expected signs of

elasticity, it seems that the first-differenced version of source-differentiated AIDS model also performs better than the un-differenced of the source-differentiated AIDS model.

In addition to elasticities, the two models are compared on the basis of goodness of fit, as measured by the weighted mean square error. Table 9 presents the weighted mean square error of two models. Evidently, the first-differenced version of source-differentiated AIDS model outperforms the un-differenced version since the weighted mean square error of the former is smaller than the latter. Hence, the first-differenced version of the source-differentiated AIDS model seems to be the better fit.

Table 10 gathers the price and income elasticities of import demand for fresh and canned mushroom obtained from the first-differenced version of the source-differentiated AIDS model. All the elasticities that are statistically significant at five or one percent level are highlighted in bold. Table 11 provides in words a concise summary of price and expenditure responsiveness of fresh and canned mushrooms. The summary isolates only the statistically significant elasticities. Empty cells represent statistically insignificant ones, implying no response or changes in prices or expenditures.

Table 8a

Estimated price elasticities of demand for fresh mushrooms: source-differentiated AIDS model and first-differenced version of source-differentiated AIDS model.

	Fresh From:									
	Canada		China		Mexico		South Korea		ROW	
	A	F	A	F	A	F	A	F	A	F
Canada	-0.526***	-0.580***	-0.009	-0.001	0.073**	0.075**	0.006	0.011	-0.038*	-0.035**
	(0.152)	(0.142)	(0.042)	(0.031)	(0.036)	(0.033)	(0.012)	(0.011)	(0.019)	(0.017)
China	0.033	0.146	0.550	-0.060	-0.245	-0.032	0.040	0.029	0.073	0.084
	(0.823)	(0.634)	(0.487)	(0.405)	(0.335)	(0.279)	(0.076)	(0.076)	(0.142)	(0.138)
Mexico	1.080**	1.157**	-0.183	-0.028	-1.551***	-1.765***	0.030	0.046	-0.013	0.002
	(0.503)	(0.463)	(0.237)	(0.196)	(0.279)	(0.227)	(0.050)	(0.039)	(0.084)	(0.067)
South Korea	0.437	0.704	0.080	0.063	0.098	0.146	-0.961***	-0.955***	0.017	0.081
	(0.513)	(0.488)	(0.151)	(0.152)	(0.141)	(0.110)	(0.086)	(0.087)	(0.081)	(0.105)
ROW	-1.499**	-1.511**	0.115	0.132	-0.040	-0.014	0.008	0.060	-1.477***	-1.254***
	(0.665)	(0.630)	(0.251)	(0.246)	(0.210)	(0.170)	(0.072)	(0.093)	(0.165)	(0.219)

	Canned From:									
	China		India		Indonesia		Netherlands		ROW	
	A	F	A	F	A	F	A	F	A	F
Canada	0.154	0.172*	-0.123**	-0.126**	-0.003	0.080	0.127*	0.108*	0.088***	0.082***
	(0.097)	(0.088)	(0.056)	(0.056)	(0.103)	(0.095)	(0.063)	(0.054)	(0.008)	(0.009)
China	-0.729	-0.190	0.108	0.168	0.657	0.416	-0.200	-0.242	-0.015	-0.123***
	(0.536)	(0.451)	(0.338)	(0.296)	(0.761)	(0.665)	(0.364)	(0.370)	(0.042)	(0.032)
Mexico	-0.090	-0.239	0.460**	0.426**	-0.117	0.053	0.087	0.077	0.071**	0.190***
	(0.347)	(0.271)	(0.220)	(0.185)	(0.486)	(0.440)	(0.227)	(0.173)	(0.027)	(0.021)
South Korea	-0.091	-0.109	0.652*	0.636*	0.351	0.369	0.036	-0.066	-0.405***	-0.436***
	(0.511)	(0.502)	(0.343)	(0.364)	(0.337)	(0.349)	(0.341)	(0.331)	(0.045)	(0.046)
ROW	2.051***	1.682**	-0.934**	-0.395	0.648	0.700	-0.439	-0.567	1.039***	0.451***
	(0.566)	(0.634)	(0.354)	(0.435)	(0.545)	(0.552)	(0.361)	(0.476)	(0.043)	(0.046)

Notes: ROW: the rest of the world; F: first-differenced version of source-differentiated AIDS model; A: source-differentiated AIDS model. The numbers in parentheses right underneath the elasticity are standard errors. Single, double, and triple asterisks (*) represent significance at 10 percent, 5 percent, 1 percent levels, respectively.

Table 8b

Estimated price elasticities of demand for canned mushrooms: source-differentiated AIDS model and first-differenced version of source-differentiated AIDS model.

	Canned From:									
	China		India		Indonesia		Netherlands		ROW	
	A	F	A	F	A	F	A	F	A	F
China	-1.302***	-1.214***	-0.199	-0.318*	-0.277**	-0.346***	-0.252	-0.224	-0.267***	-0.222***
	(0.319)	(0.280)	(0.169)	(0.167)	(0.122)	(0.115)	(0.162)	(0.143)	(0.026)	(0.024)
India	0.233	-0.019	0.077	0.019	0.256	0.282	-0.396	-0.187	0.243***	0.458***
	(0.421)	(0.424)	(0.368)	(0.428)	(0.198)	(0.210)	(0.269)	(0.264)	(0.045)	(0.046)
Indonesia	-0.001	-0.184	0.213	0.207	-0.702	-0.840	-0.020	0.037	0.023***	-0.128***
	(0.282)	(0.271)	(0.179)	(0.191)	(0.549)	(0.541)	(0.188)	(0.192)	(0.022)	(0.021)
Netherlands	-0.186	-0.200	-0.525	-0.341	-0.052	-0.016	-0.747*	-0.789**	0.381***	0.153***
	(0.476)	(0.429)	(0.317)	(0.313)	(0.245)	(0.249)	(0.427)	(0.388)	(0.048)	(0.043)
ROW	-0.128	-0.029	0.175***	0.352***	-0.019	-0.185***	0.301***	0.137***	-1.432***	-1.315***
	(0.107)	(0.072)	(0.039)	(0.027)	(0.042)	(0.028)	(0.033)	(0.022)	(0.040)	(0.027)

	Fresh From:									
	Canada		China		Mexico		South Korea		ROW	
	A	F	A	F	A	F	A	F	A	F
China	-1.078***	-1.059***	-0.145***	-0.093**	-0.107**	-0.130***	-0.042*	-0.045*	0.073**	0.056
	(0.236)	(0.216)	(0.052)	(0.044)	(0.048)	(0.038)	(0.025)	(0.024)	(0.032)	(0.035)
India	-0.526	-0.417	0.023	0.047	0.173**	0.166**	0.081*	0.080*	-0.127**	-0.044
	(0.364)	(0.367)	(0.085)	(0.075)	(0.079)	(0.067)	(0.043)	(0.045)	(0.050)	(0.062)
Indonesia	-0.035	0.343	0.145	0.088	-0.041	0.011	0.037	0.036	0.089	0.097
	(0.471)	(0.440)	(0.178)	(0.156)	(0.161)	(0.146)	(0.039)	(0.041)	(0.072)	(0.073)
Netherlands	0.657	0.322	-0.079	-0.099	0.027	0.005	-0.003	-0.025	-0.076	-0.101
	(0.433)	(0.387)	(0.108)	(0.111)	(0.097)	(0.075)	(0.051)	(0.049)	(0.061)	(0.081)
ROW	0.228	0.136	-0.025**	-0.053***	0.009	0.044***	-0.061***	-0.068***	0.144***	0.062***
	(0.206)	(0.140)	(0.010)	(0.007)	(0.014)	(0.010)	(0.005)	(0.003)	(0.006)	(0.004)

Notes: ROW: the rest of the world; F: first-differenced version of source-differentiated AIDS model; A: source-differentiated AIDS model. The numbers in parentheses right underneath the elasticity are standard errors. Single, double, and triple asterisks (*) represent significance at 10 percent, 5 percent, 1 percent levels, respectively.

Table 9

Weighted mean square error: source-differentiated AIDS model and first-differenced version of source-differentiated AIDS model.

	Source-differentiated AIDS model	First-differenced version of source-differentiated AIDS model
Weighted mean square error	5.8897	5.8112

Table 10

Price elasticities of U.S. mushrooms import demand using first-differenced version of source-differentiated AIDS model.

	Fresh From:				Canned From:				X
	Canada	China	Mexico	South Korea	China	India	Indonesia	Netherlands	
Fresh From:									
Canada	-0.580***	-0.001	0.075**	0.011	0.172*	-0.126**	0.080	0.108*	0.215**
	(0.142)	(0.031)	(0.033)	(0.011)	(0.088)	(0.056)	(0.095)	(0.054)	(0.085)
China	0.146	-0.060	-0.032	0.029	-0.190	0.168	0.416	-0.242	-0.197
	(0.634)	(0.405)	(0.279)	(0.076)	(0.451)	(0.296)	(0.665)	(0.370)	(0.406)
Mexico	1.157**	-0.028	-1.765***	0.046	-0.239	0.426**	0.053	0.077	0.082
	(0.463)	(0.196)	(0.227)	(0.039)	(0.271)	(0.185)	(0.440)	(0.173)	(0.262)
South Korea	0.704	0.063	0.146	-0.955***	-0.109	0.636*	0.369	-0.066	-0.432
	(0.488)	(0.152)	(0.110)	(0.087)	(0.502)	(0.364)	(0.349)	(0.331)	(0.578)
Canned From:									
China	-1.059***	-0.093**	-0.130***	-0.045*	-1.214***	-0.318*	-0.346***	-0.224	3.596***
	(0.216)	(0.044)	(0.038)	(0.024)	(0.280)	(0.167)	(0.115)	(0.143)	(0.305)
India	-0.417	0.047	0.166**	0.080*	-0.019	0.019	0.282	-0.187	-0.384
	(0.367)	(0.075)	(0.067)	(0.045)	(0.424)	(0.428)	(0.210)	(0.264)	(0.582)
Indonesia	0.343	0.088	0.011	0.036	-0.184	0.207	-0.840	0.037	0.333
	(0.440)	(0.156)	(0.146)	(0.041)	(0.271)	(0.191)	(0.541)	(0.192)	(0.262)
Netherlands	0.322	-0.099	0.005	-0.025	-0.200	-0.341	-0.016	-0.789**	1.092*
	(0.387)	(0.111)	(0.075)	(0.049)	(0.429)	(0.313)	(0.249)	(0.388)	(0.549)

Notes: X: expenditure elasticities. The numbers in parentheses right underneath the elasticity are standard errors. Single, double, and triple asterisks (*) represent significance at 10 percent, 5 percent, 1 percent levels, respectively.

Table 11
Summary of price and expenditure responsiveness of U.S. fresh and canned mushroom import demand.

Fresh mushroom imports										
		Price of fresh mushrooms from:				Price of canned mushrooms from:				Expenditure
Imports from:		Canada	China	Mexico	South Korea	China	India	Indonesia	Netherlands	
	Canada	Inelastic		Weak Substitute			Weak Complement			Inelastic
	China									
	Mexico	Strong Substitute		Elastic			Weak Substitute			
	South Korea				Inelastic					
	Canned mushroom imports									
		Price of fresh mushrooms from:				Price of canned mushrooms from:				
Imports from:		Canada	China	Mexico	South Korea	China	India	Indonesia	Netherlands	
	China	Strong Complement	Weak Complement	Weak Complement		Elastic		Weak Complement		Highly Elastic
	India			Weak Substitute						
	Indonesia									
	Netherlands								Inelastic	

CHAPTER 6: SUMMARY AND CONCLUSIONS

Imported fresh mushrooms accounted for 11 percent of the fresh mushrooms consumption in 2015, increasing by 74.6 percent since 1995; and imported processed mushrooms accounted for 78 percent of the processed mushrooms consumption in 2015, increasing by 74.6 percent since 1995. Canada is by far the largest exporter of fresh mushrooms to the U.S. but, more recently, the share of total fresh mushroom imports has been shifting from Canada to China, Mexico and South Korea. China is the largest exporter of canned mushrooms. Since 2003, India, Indonesia, and Netherlands have become the major suppliers of canned mushrooms to the U.S. market. Together with China, they accounted for 70 percent of total U.S. canned mushrooms imports.

Despite increased importance mushroom imports in total U.S. consumption, little is known about the structure of mushroom import demand beyond tabular information on imports from different sources. While such information is necessary, it is not sufficient for understanding the structure of import demand. Understanding demand stucture requires econometric estimation of demand responsiveness of fresh and canned mushrooms by source to changes in expenditures, own prices, and prices of fresh and canned mushrooms imported from competing sources.

To that end, the purpose of this thesis is to estimate import demand elasticities for fresh and canned mushrooms during the period 2002-2015 by 1) first using a source-differentiated Almost Ideal Demand System (AIDS) model and a source-differentiated Rotterdam model; 2) selecting between the two models based on two specification tests,

and 3) choosing between the un-differenced and first-differenced version of the model selected using the specification tests.

Results of the two specification tests show that the first-differenced version of the source-differentiated AIDS model is preferred to the source-differentiated Rotterdam model. Using the mean-squared error as a measure of goodness of fit, the first-differenced AIDS is a slightly better fit than AIDS in levels.

The conclusions from the elasticity estimates are as follows. Among the top four exporters of fresh mushrooms to the U.S. (Canada, China, Mexico and South Korea), Canada and South Korea face an inelastic U.S. import demand, while Mexico faces a highly elastic one. U.S. import demand from China is price insensitive. Mexican fresh mushrooms imports are weak substitutes for Canadian mushrooms, but Canadian mushrooms are strong substitutes for Mexican mushrooms. Canned mushrooms imports from India are weak complements for fresh mushrooms imports from Canada and weak substitutes for imports of fresh mushrooms from Mexico. Only Canadian mushroom imports are sensitive to rising expenditures on mushrooms, but the expenditure elasticity is inelastic.

Among the top four exporters of canned mushrooms to the U.S. (China, India, Indonesia, and the Netherlands), the own-price elasticity of mushrooms import demand from China is elastic and the expenditure elasticity is highly elastic. The own-price elasticity of mushrooms import demand from the Netherlands is inelastic. U.S. import demand from India and Indonesia are price insensitive. There is a weak complementarity between canned mushrooms imported from Indonesia and fresh mushrooms imported from China and Mexico and canned mushrooms imported from China. However, fresh

mushrooms imported from Canada are strong complements with canned mushrooms imported from China. Imports of fresh mushrooms from Mexico are weak substitutes for imports of canned mushrooms from India.

The elasticity estimates have implications for exporters of mushrooms to the U.S. First, because import demand for Canadian fresh mushrooms is more inelastic than import demand for Chinese canned mushrooms, Canada, the leading exporter of fresh mushrooms, stands to gain in revenue from rising mushroom prices than China, the leading exporter of canned mushrooms. Second, since the expenditure elasticity of fresh mushroom imports from Canada is inelastic and the expenditure elasticity of canned mushroom imports from China is elastic, Chinese exporters stand to gain more from rising U.S. expenditures on canned mushrooms than Canadian exporters of fresh mushrooms.

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