New Demand for Old Food: the U.S. Demand for Olive Oil

Bo Xiong, William Matthews, Daniel Sumner ♣

Abstract

U.S. consumption of olive oil has tripled over the past twenty years, but nearly all olive oil continues to be imported. Estimation of demand parameters using monthly import data reveals that demand for non-virgin oil is income inelastic, but virgin oils have income elasticities above one. Moreover, demand for oils differentiated by origin and quality is price-elastic. These olive oils are highly substitutable with each other but not with other vegetable oils. News about the health and culinary benefits of olive oil and the spread of Mediterranean diet contribute significantly to the rising demand in the United States.

Keywords: olive oil, food demand, Mediterranean diet, health, food trends

JEL classification: Q11, Q17

♣ Bo Xiong, boxiong@ucdavis.edu, the corresponding author, and William Matthews, wamatthews@ucdavis.edu, are postdoctoral research scholars at the Agricultural Issues Center, University of California. Daniel Sumner, dasumner@ucdavis.edu, is the director of the Agricultural Issues Center, University of California and the Frank Buck Jr. Professor in the Department of Agricultural and Resource Economics at UC Davis. The authors thank Julian Alston, Samir Mili, Sebastien Pouliot, and Luca Salvatici for helpful comments, the USITC olive oil team for exchanges of ideas, and Georgi Gabrielyan for his assistance in data collection.

1. Introduction

Diets and food demands are changing globally. Consumers are paying increasing attention to health and flavors and broadening their consumption basket to include food items that were once considered exotic.[1] In recognition of food trends, agricultural economists have expanded the focus of food demand research to understand the impacts of diet and health knowledge on consumption patterns (e.g., Kaabia, Angulo, and Gil, 2001; Tiffin and Arnoult, 2010).

Recently, olive oil is making news and raising important economic and policy issues. In September 2012, *The Economist* discussed the spread of the appetite for olive oil beyond the Mediterranean region (*The Economist*, 2012). Based on the new clinical evidence published in the *New England Journal of Medicine* (Estruch et al., 2013), the *New York Times* in February 2013 highlighted the effectiveness of olive oil in warding off heart attack and stroke (Kolata, 2013). In the policy arena, the United States International Trade Commission (USITC) held a public hearing in December 2012 to assess the U.S. competitiveness in olive oil in the context of global market trends and policies, as part of a larger project requested by the U.S. Congress (USITC, 2012). At the USITC hearing, U.S. olive oil industry representatives expressed concerns about European olive oil policies as well as quality standards and compliance issues. In response, the European olive industry asked the European Commission to be ready to act on the potential threats of the U.S. trade barriers (Butler, 2012).

Despite the rising importance of olive oil in markets outside of the Mediterranean region, we find no econometric studies of olive oil demand in those markets. We fill this gap by providing the first estimates that characterize the demand for olive oil in the United States, a

---

[1] See for example the "What We Eat in America" national food survey conducted by the U.S. Department of Health and Human Services and the U.S. Department of Agriculture.

rapidly expanding market and the largest import destination for olive oil (excluding intra-EU trade).

In this article we estimate the U.S. demand for olive oil and investigate several demand drivers, such as relative prices, personal income, and dietary information. We highlight rising consumer awareness of the health benefits of olive oil and the spread of Mediterranean diet in the United States. We use U.S. monthly imports of olive oil over the period January 1990 through December 2012 to estimate a demand system for olive oils. We find that the U.S. demand for non-virgin oil is income inelastic, but virgin oils have income elasticities above one. Olive oils of different origins and qualities are highly substitutable with each other but not with other vegetable oils. News about the healthiness of olive oil and the spread of Mediterranean diet contributes significantly to the expansion of olive oil demand in the United States.

1.1. The world and the U.S. markets

Global production of olive oil has more than doubled from about 1.5 million metric tons in 1990 to more than 3 million tons in 2012 (International Olive Council). Major producing regions that surround the Mediterranean Sea produce about 95 percent and consume about two-thirds of the world's olive oil. Meanwhile, new markets have been growing quickly. In the United States more than 300,000 tons of olive oil were sold in 2012, tripling the quantity sold in 1990. Nevertheless, olive oil remains a tiny share in U.S. consumption of all vegetable oils, which was more than 12 million tons in 2012.[2] While consumption has grown, the U.S. production of olive oil has remained low. The U.S. olive industry only supplied 4,000 tons of olive oil in 2012, about 1.3 percent of olive oil marketed in the United States.

The rising demand for olive oil in the United States has been met by imports from Southern Europe, Northern Africa, and the Middle East. More than half of the U.S. olive oil

---

[2] See Table 06 under the menu "Oilseeds" of the PSD online, USDA. http://www.fas.usda.gov/psdonline/.

imports are shipped from Italy.[3] Although the market share of shipment from Italy has declined

in recent years, U.S. olive oil imports from Italy were still worth more than $500 million in 2012,

while U.S. imports of olive oils from Spain were worth about $200 million. Other major

suppliers of olive oils to the United States include Greece, Turkey, Tunisia, and Morocco.

1.2. Olive oil as a specialty vegetable oil

Compared with ordinary cooking oils (e.g., soybean oil, corn oil, palm oil, and peanut

oil), olive oil features unique health benefits and is a major part of the Mediterranean diet.

Research has documented that olive oil is effective in lowering levels of blood cholesterol,

reducing the risk of breast cancer, and helping calcium absorption (Owen et al., 2000; Tuck and

Hayball, 2002; Sofi et al., 2008). More recently, Estruch et al. (2013) further documented that

olive oil is a primary ingredient in the Mediterranean diet that contributes to long life and good

health.

The industry standard for quality of olive oil is closely related to the method of

extraction. According to the International Olive Council (IOC) standards, olive oil produced

without chemical treatments and reaching acidity of less than 2 percent is qualified as "virgin

olive oil" (International Olive Council, 2011). Virgin olive oil is sold at premium prices. Similar

quality designations are used in the United States, but the retail grades and quality standards

developed by the International Olive Council are not binding in the United States. In 2010 the

U.S. Department of Agriculture launched a quality monitoring program for olive oils marketed in

the United States (USDA-AMS), but the program is voluntary. The USITC public hearing in

December 2012 engaged stake holders in the domestic industry in part to consider possible U.S.

quality control measures and other public policies for the olive oil market. In that context some

---

[3] From the custom data one can identify where the olive oil is shipped from, rather than where the olive oils are actually produced. For example, olive oils departing from the Italian ports might be extracted from olives grown in other countries.

have raised the potential of a federal marketing order to implement mandatory grading of all olive oil marketed in the United States.

The rest of the article is organized as follows. We describe the data and highlight the stylized facts in Section 2. After outlining the econometric specification in Section 3, we present the empirical results and discuss the implications in Section 4. In the last section we offer conclusions and directions for future research.

2. Data and market trends

2.1. The import data

Since all but a tiny fraction of olive oil consumed in the United States is imported, we use the U.S. custom data to measure consumption quantities. Specifically, we use monthly olive oil import series for the period January 1990 through December 2012.[4] We compute the import prices as import values divided by import quantities. We exclude tariffs from our analysis because U.S. duty rates for olive oils are low and have not changed over the past two decades.[5] According to the product classifications at the 10-digit level, U.S. olive oil imports can be differentiated along three characteristics. First, based on the method of extraction, olive oils are either qualified as virgin or not.[6] Second, olive oil imports arrive at U.S. ports either in small containers (less than 18 kilograms) or in large bulk containers (larger than 18 kilograms). Third, olive oil imports can be differentiated by exporting country. Next we review the three characteristics and propose a method of product aggregation that allows a feasible empirical specification while retaining the consistency with consumer theory.

---

[4] The 10-digit product codes for olive oil imports in the USITC database are: 1509102000, 1509104000, 1509902000, and 1509904000. Note that olive oils blended with other types of vegetable oils are not considered.
[5] The general import tariff rates applied to olive oil in small and large containers are 5 and 3.4 cents per kilogram. Preferential treatment was granted to Jordan in 2002, Chile in 2004, Morocco in 2006, and Peru in 2010. On an Ad Valorem basis, the tariff rates are less than one percent. http://www.usitc.gov/tata/hts/index.htm
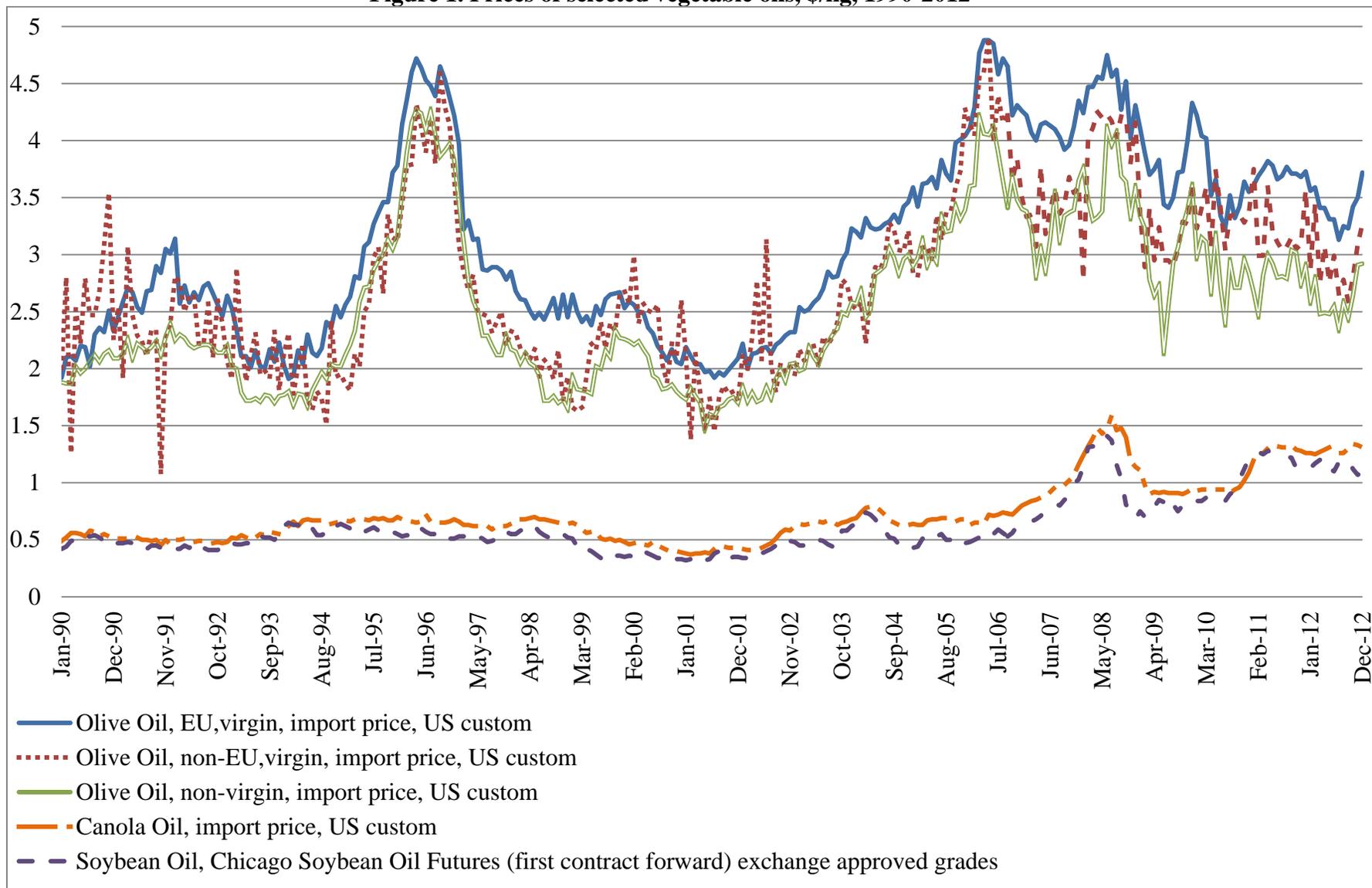[6] No "extra virgin" designation is available, either under the 10-digit Expert code or under the 8-digit Harmonized System code.

2.2. The classification of products

We discuss the classification of olive oils by quality (virgin versus non-virgin), container size (less or larger than 18 kilograms), and the country of export.

Figure 1 shows the relative prices among different types of olive oils and between olive oil and other major vegetable oils. Virgin olive oils are sold at prices higher than non-virgin olive oils in the United States. In 2012 the price of virgin olive oil was about $3.30 per kilogram, while the price of non-virgin olive oil was about $2.60. Furthermore, virgin olive oils are more likely to be sold in retail stores while non-virgin olive oils are primarily used in food service or food processing. Therefore, our demand system differentiates olive oils by virgin and non-virgin.

Figure 1. Prices of selected vegetable oils, $/kg, 1990-2012

Legend:
- Olive Oil, EU,virgin, import price, US custom
- Olive Oil, non-EU,virgin, import price, US custom
- Olive Oil, non-virgin, import price, US custom
- Canola Oil, import price, US custom
- Soybean Oil, Chicago Soybean Oil Futures (first contract forward) exchange approved grades

Sources: US custom data are from USITC and other prices are from IMF primary commodity prices.

The share of olive oils shipped in containers larger than 18 kilograms increased from 20 percent in 1990 to about 30 percent in 2012. In particular, a higher proportion of imports are shipped in large containers for non-virgin olive oils and olive oils shipped from non-EU countries. One plausible reason is that these olive oils are more likely to be marketed via food service or food processing. From the perspective of end consumers, however, information about the container size is unavailable and likely irrelevant. Therefore, to conserve degrees of freedom in our econometric specification, we do not differentiate olive oils by the size of containers in which they reach the U.S. ports.

Finally, the export origin is potentially important for olive oil. We first define two broad sourcing regions for U.S. olive oil imports: EU and non-EU. We hypothesize that consumers associate EU olive oils with higher quality or better reputation. Menapace et al. (2011) finds in a willingness-to-pay study that Canadian consumers value Italian extra virgin olive oils significantly more than other EU extra virgin oils. To consider the potential origin premium attached to Italian olive oils, we also use Italian and non-Italian as our alternative method to group countries of export. We do not differentiate non-virgin olive oils by source because the price difference is negligible. In summary, we use two product classification schemes for the U.S. olive oil imports each of which has three olive oil types. These two classification schemes are: (a) virgin oils imported from EU countries, virgin oils imported from elsewhere, and non-virgin oils; (b) virgin oils imported from Italy, virgin oils imported from other countries, and non-virgin oils.

2.3. *The demand shifters*

Olive oil is a traditional food in the Mediterranean, but has not been widely used in the United States and while growing rapidly still comprises a small share of vegetable oil used in the

United States. We hypothesize that the rising consumer awareness of the health benefits of olive oil, and Americans' growing appetite for the Mediterranean diet in general, likely contributes to the growth of U.S. olive oil market. To incorporate these plausible demand shifters, we use the number of articles published in U.S. newspapers, newswires, blogs, broadcast transcripts, business journals, and periodicals that report the healthiness or culinary benefits of olive oil. Specifically, we search within the News Bank database (http://www.newsbank.com/) for articles containing the key words "health" and "olive oil", or "cholesterol" and "olive oil", or "heart" and "olive oil" in their lead paragraphs. We also retrieve news articles on the trendiness of olive oil by identifying articles with the key words "taste" and "olive oil", or "recipe" and "olive oil" in the lead paragraphs. Finally, we sum the two stocks of articles after removing any double counting in the two sets of searches.

News articles about the healthiness or culinary benefits of olive oil can affect the consumption through two closely related but distinct channels. First, the accumulated knowledge of the benefits of olive oil changes U.S. consumers' information set. That is, we measure the long-run impacts of the relevant information on consumers' demand for olive oil. Second, recent publications serve as reminders of the stock of information about which consumers may be aware. An additional bit of information may have limited duration impacts on consumer's demand as well as an effect through the addition to the stock of knowledge. To capture both the knowledge and the limited duration reminder effects, we create two variables from the above-defined news articles. First, we count the total number of articles, either addressing the healthiness or the culinary benefits of olive oil, published one year ago or earlier. Second, we count the total number of news articles published within the past twelve months.[7]

---

[7] We also consider 6-month and 18-month period as the alternative ways to differentiate the knowledge and reminder effects of news articles. Both effects are robust to the alternative specifications.

In addition, to control for Americans' changing appetite for Mediterranean food in general, we use U.S. monthly import of Italian-style cheese (e.g., Reggiano, Parmesan, Provolone, Provoletti, Sbrinz, and Goya). Compared with articles on olive oil, the import of Italian-style cheese reflects a broader change in American dietary habits and partially controls for the substitutability or complementarity of olive oil and other Mediterranean foods.

Next we address the substitution between olive oil and other vegetable oils. Two facts are evident from Figure 1. First, olive oil is far more expensive than canola or soybean oil. [8] Second, the prices of canola and soybean oils are highly correlated, but the prices of olive oils exhibit unique patterns.[9] Statistically, the correlation of olive oil price is about 0.21 with soybean oil price, and 0.32 with canola oil price.[10] More than twenty years ago Pierani and Rizzi (1991) documented the low substitutability of olive oil with other vegetable oils in Italy at that time. They found that the cross-price elasticity of demand for olive oil in Italy was less than 0.08. Similarly, Mili (1996) found that sunflower oil, the major alternative vegetable oil in Spain, substitutes for non-virgin but not virgin olive oils. We include the U.S. monthly import price of canola oil to account for the potential substitution between olive oil and other vegetable oils. Finally, we include data on U.S. personal income, U.S. population, and the U.S. monthly Consumer Price Index for foods. Appendix A compiles information on all data series and sources.

2.4. Summary statistics

---

[8] The U.S. monthly import price of canola oil is computed as the import value of rapeseed oil divided by the import quantity of rapeseed oil. Since most of the imported rapeseed oils are canola oils sourced from Canada, we can use the unit value of rapeseed oil to represent the price of canola oil.

[9] The prices of palm oil and sunflower oil also move along with the price of soybean or canola oil. See the IMF commodity prices for details.

[10] In computing the correlations, prices are deflated by CPIs. Olive oils are sometimes blended with canola oils in food service use. For example, the Corning Olive Oil company of California offers a special blend of 80% canola oil and 20% olive oil for pan frying and deep frying at high temperatures.
http://www.corningoliveoil.com/index.php?main_page=indexandcPath=16

We present in Table 1 summary statistics of the data. To illustrate the market trends, we also provide separate summary statistics over the first five years, 1990-1994, and the last five years, 2008-2012. As shown in Table 1, the rising quantity of olive oil in the United States is largely confined to the increased consumption of virgin oils. The monthly per-capita consumption of virgin olive oil from EU sources has grown from 10 grams in early 1990s to nearly 40 grams in recent years. Moreover, the market share of virgin oils imported from non-EU countries has increased from about zero to more than 10 percent. In contrast, the U.S. import of non-virgin olive oil has been stagnant.

While there is no clear trend in the prices of olive oils over the past two decades (as illustrated in Figure 1), the ranking of prices of three types of olive oils has been consistent over time. The import price of virgin oil sourced from EU is higher than virgin oil sourced from elsewhere, and non-virgin oil is sold at an even lower price.

Our count of articles on the healthiness or culinary benefits of olive oil begins in 1980 but the publications before 1990 were few. The number of articles rose to about 50 per month in 1990s. Numbers of articles published declined in the early 2000s, but climbed again after 2004. In recent years, the number of articles varies substantially around an average of 50 per month.

Table 1. Summary statistics for U.S. olive oil demand

Variable	Mean full sample	Mean Jan/90-Dec/94	Mean Jan/08-Dec/12
Per-capita consumption of EU/Virgin, gram	25.31	10.00	39.28
	(12.38)	(2.88)	(5.80)
Per-capita consumption of Non-EU/Virgin, gram	4.77	1.11	10.05
	(4.54)	(1.55)	(4.06)
Per-capita consumption of Italian/Virgin, gram	17.94	6.78	26.70
	(8.71)	(2.24)	(3.94)
Per-capita consumption of Non-Italian/Virgin, gram	12.13	4.33	22.63
	(8.30)	(2.52)	(6.82)
Per-capita consumption of Non-Virgin, gram	24.67	23.68	22.88
	(5.47)	(4.76)	(5.35)
Price of EU/Virgin, $/kg	3.11	2.39	3.79
	(0.82)	(0.31)	(0.41)
Price of Non-EU/Virgin, $/kg	2.77	2.25	3.33
	(0.76)	(0.44)	(0.46)
Price of Italian/Virgin, $/kg	3.16	2.43	3.93
	(0.85)	(0.36)	(0.40)
Price of Non-Italian/Virgin, $/kg	2.91	2.27	3.43
	(0.76)	(0.26)	(0.44)
Price of Non-Virgin, $/kg	2.56	2.01	2.98
	(0.70)	(0.20)	(0.44)
Per-capita personal income, $1000	30.77	20.75	40.69
	(7.56)	(1.11)	(1.46)
Price of canola oil, $/kg	0.73	0.54	1.17
	(0.28)	(0.06)	(0.20)
# of accumulated articles, up to 12 months ago	4047	764	9441
	(3281)	(307)	(830)
# of articles, in the past 12 months	455	220	513
	(178)	(30)	(162)
Per-capita import of Italian cheese, gram	2.19	1.19	3.12
	(1.15)	(0.73)	(0.79)
CPI, June 2000=1	1.04	0.81	1.28
	(0.17)	(0.04)	(0.04)

Note: Standard deviations are in parentheses.

3. The econometric specification

3.1. The choice of demand system

      With the assumption that the total expenditure on the commodities of interest is separable from the overall budget, complete demand systems can be derived to characterize consumption patterns in a way consistent with consumer theory (Deaton and Muellbauer, 1980).[11] Previous studies on the U.S. consumption of vegetable oils treated "oils and fats" as a group and focused on major vegetable oils such as corn, cottonseed, and soybean oils (e.g., Chern, Loehman, and Yen, 1995). The omission of olive oil in earlier research was due to the tiny share of olive oil, which accounted for about 2.5 percent of all vegetable oils in 2012 (USDA-FAS, oilseeds reports). Rather than focusing on all vegetable oils, we treat all olive oils as the relevant group and hence treat Americans' total expenditure on olive oils as separable from other purchases. With this assumption, we formulate a conditional demand system that characterizes the quantities demanded for individual types of olive oils and investigate the substitution patterns within the varieties of olive oil and between olive oil and canola oil.

      A major caveat of separating the expenditure on olive oil from the overall budget is that the expenditure on olive oil is simultaneously determined with quantity demanded for all types of olive oils. Two remedies exist in the literature. The first applies the instrumental variable approach to the demand system (e.g., LaFrance, 1991). This approach takes advantage of extra variables that affect the consumption patterns only through influencing the total expenditure on the commodity group. The second approach models the demand equation and the expenditure equation simultaneously (e.g., Dhar, Chavas, and Gould, 2003). We choose to estimate simultaneous equations because it sheds light on the determinants of the total expenditure on olive oils and delivers income elasticities using estimates from both equations.

---

[11] See Okrent and Alston (2011) for a recent survey on the developments in the literature of food demand.

Since the separability assumption in the complete demand models may not hold, to check robustness, we also estimate an incomplete demand system in which the quantity demanded for olive oil is explained by prices of olive oils, personal income, and other shifters. We discuss the associated results in section 4.2.

3.2. The AIDS model with endogenous variables

We use the Almost Ideal Demand System (AIDS) as the econometric specification for the olive oil demand. Specifically, the U.S. demand for olive oils is characterized as:

$$(1) \quad s_{it} = \alpha_i + \beta_i \ln(m_t) - \beta_i \ln P_t + \sum_j \gamma_{ij} \ln(p_{jt}) + \theta_i trend_t + \sum_{n=1}^{12} \chi_{in} T_n + \mu_{it},$$

$$(2) \quad \begin{aligned} \ln(m_t) &= \delta + \phi \ln P_t + \varphi \ln(y_t) + \eta \ln(p_{ct}) + \lambda \ln(cpi_t) + \omega \ln(cheese_t) \\ &\quad + \tau \ln(Kart_t) + \rho \ln(Rart_t) + v_t, \end{aligned}$$

where i, j are the product indices for the three types of olive oils, t denotes period, i.e., $t \in \{1, 2, ..., 276\}$. The dependent variable s_{it} in (1) is the expenditure share of olive oil i. Variable m_t is U.S. total expenditure on olive oil; p_{jt} is the price of olive oil j; $\ln P_t$ is the AIDS price index, which we approximate using the corrected Stone price index (Moschini, 1995). Specifically, $\ln P_t \approx \sum_j w_{j0} \ln p_{jt}$, where w_{j0} is the expenditure share of olive oil j over the period January 2010 through December 2012.[12] Other shifters in (1) include a linear time trend and monthly dummy variables to control for the seasonal variations in consumptions. The usual idiosyncratic error term is denoted with μ_{it}.

---

[12] We evaluate the corrected Stone price index at the recent expenditure shares to reflect the current market.

Equation (2) deals with the endogeneity of the expenditure variable.[13] Intuitively, we explain U.S. total expenditure on olive oil using the corrected Stone price index, $\ln P_t$, U.S. per-capita personal income, y_t, the price of canola oil, p_{ct}, the monthly CPI, cpi_t, U.S. per-capita import of Italian-style cheese, and the knowledge effect, $Kart_t$, and the reminder effect, $Rart_t$, of news articles on the healthiness or trendiness of olive oil.[14]

3.3. Estimation procedure and caveats

To complete the demand system (1)-(2), we adopt the following parameter restrictions:

(3a) $\gamma_{ij} = \gamma_{ji}$ (symmetry),

(3b) $\sum_j \gamma_{ij} = 0$ (homogeneity within the group of olive oils),

(3c) $\sum_i \alpha_i = 1$, $\sum_i \beta_i = 0$, $\sum_i \chi_{in} = 0$, and $\sum_i \theta_i = 0$ (shares adding up to one),

(3d) $\theta_1 / s_1 = \theta_2 / s_2$ (common time trend for both types of virgin oils)

(3e) $\phi + \varphi + \eta + \lambda = 1$ (homogeneity outside of the group of olive oils).

We conduct two validation exercises before estimation. First, we implement the Dickey-Fuller test (Dickey and Fuller, 1979) to check the stationarity of the expenditure shares in (1). We find that none of the expenditure shares contains unit roots.[15] Therefore, the demand system can be estimated in its original form rather than in the differenced form. Second, we check the time serial correlation in (1) using the Wooldridge test for panel data (Wooldridge, 2002). We

---

[13] The specification in (2) resembles the expenditure equation used by Thompson (2004).
[14] The identification of the separate effects of healthiness and trendiness of olive oil is not feasible because the two series are highly correlated.
[15] See Appendix B for the results of the unit-root test.

accept the null hypothesis that (1) is not subject to first-order autoregressive error structure at the usual confidence level.[16]

Finally, we examine the possible endogeneity of prices in the demand system. The U.S. olive oil prices might be endogenous to the U.S. olive oil import quantities for two reasons. First, the use of unit values as measurements of prices may introduce a mechanical negative correlation between the price and quantity series in the presence of measurement error. We consider the potential measurement error to be small in magnitude on two grounds. First, rounding error is negligible in the U.S. custom data because values are recorded up to the last digit of dollars and quantities are down to kilograms. Second, random reporting errors tend to cancel out because the value and quantity data that are used to compute the price series are the summation of more than a dozen U.S. ports that actively import olive oils every month.

Another potential source of endogeneity is the effect of the U.S. quality demanded and the world price of olive oil. However, such feedback effects are limited because the U.S. market accounts for less than 10 percent of the world consumption of olive oil (see Section 1.1). To further check the exogeneity of the U.S. import prices, we conduct the Hausman-Durbin-Wu test for the import prices of virgin and non-virgin oils, using annual dummy variables based on marketing years as the instrumental variables. The test results fail to reject the hypothesis that U.S. is a price-taker in the market for virgin olive oil at the five percent confidence level, and in the market for non-virgin olive oil at the one percent confidence level.[17]

4. Results and discussions

4.1. The benchmark

---

[16] See Appendix B for the results of the serial correlation test.
[17] See Appendix C for the Hausman-Durbin-Wu tests.

We estimate the demand system (1)-(3) using 3SLS. Specifically, we report, in Table 2, four sets of regressions: with EU virgin oil or Italian virgin oil separated (in the two panels of Table 2), with or without addressing the potential endogeneity of U.S. total expenditure on olive oils (with italics for estimates without accounting for potential endogeneity). We present the elasticities of demand in Table 2.[18] To make results directly relevant to the current market, we evaluate all elasticities at the market shares over the period January 2010 to December 2012.

---

[18] The estimated coefficients are presented in Appendix D.

Table 2. Price elasticities of U.S. demand for olive oils

Demand for olive oil, of type	Product classification I		
	EU/Virgin	**Non-EU/Virgin**	**Non-Virgin**
Expenditure share	60%	13%	27%
Price of EU/Virgin	-0.437 (0.027)	0.889 (0.065)	0.553 (0.059)
	-0.418 (0.027)	*0.869 (0.063)*	*0.518 (0.058)*
Price of Non-EU/Virgin	0.189 (0.014)	-1.221 (0.064)	0.157 (0.033)
	0.185 (0.013)	*-1.236 (0.063)*	*0.173 (0.032)*
Price of Non-Virgin	0.249 (0.026)	0.333 (0.070)	-0.710 (0.070)
	0.233 (0.026)	*0.367 (0.067)*	*-0.691 (0.068)*
Expenditure	1.134 (0.020)	1.409 (0.032)	0.508 (0.052)
	1.033 (0.010)	*1.320 (0.025)*	*0.775 (0.026)*

Demand for olive oil, of type	Product classification II		
	Italy/Virgin	**Non-Italy/Virgin**	**Non-Virgin**
Expenditure share	42%	31%	27%
Price of Italy/Virgin	-0.921 (0.043)	0.845 (0.043)	0.454 (0.055)
	-0.913 (0.042)	*0.841 (0.043)*	*0.447 (0.055)*
Price of Non-Italy/Virgin	0.628 (0.032)	-0.972 (0.054)	0.147 (0.052)
	0.624 (0.032)	*-0.958 (0.053)*	*0.135 (0.051)*
Price of Non-Virgin	0.293 (0.036)	0.127 (0.045)	-0.601 (0.071)
	0.289 (0.035)	*0.117 (0.044)*	*-0.582 (0.070)*
Expenditure	1.149 (0.022)	1.112 (0.024)	0.642 (0.055)
	1.065 (0.013)	*1.062 (0.015)*	*0.828 (0.028)*

Note: Standard errors are in parentheses. The estimates from the AIDS model without addressing the expenditure endogeneity are in *Italics*. The Hausman test rejects the hypothesis that "the difference in coefficients is not systematic" for both methods of product classifications at the five percent confidence level. Price elasticities are compensated elasticities based on expenditure shares in the conditional demand system. All elasticities are evaluated at the market shares over the period January 2010 to December 2012.

We first discuss the price elasticities of demand in Table 2.[19] We find that the U.S. price elasticity of demand for EU virgin oils is -0.437. The U.S. demand for non-EU virgin olive oil is estimated to be price-elastic, with the own price elasticity above one. The own price elasticity of demand for non-virgin oil is about -0.71. We also find that different types of olive oils are highly substitutable, which helps explain the relatively elastic demand we find for each individual type.

The price elasticities of demand under the alternative product classification are qualitatively similar. The main difference lies in demand for Italian virgin oils. Once we separate other EU countries from Italy and shift their virgin oils to the "Non-Italy/Virgin" category, the own price elasticity for Italian virgin oils is -0.921, much higher than that for EU virgin oils (-0.437). This result can be explained by the fact that Italy, Spain, and Greece compete for the U.S. market for virgin olive oils. Therefore, the substitutability between "Italy/Virgin" and "Non-Italy/Virgin" is higher than that between "EU/Virgin" and "Non-EU/Virgin." In addition, we affirm that it is helpful to deal with the endogeneity of the expenditure variable in the demand system. The Hausman test results reject the hypothesis that the expenditure variable is exogenous, suggesting that the U.S. total expenditure on olive oils is simultaneously determined with U.S. demand for individual olive oil varieties. We discuss expenditure responses below where full income effects are reported.

Consider next the expenditure equation (2) and factors driving the U.S. total expenditure on olive oils. Note that the two methods of product classification share the same specification of (2) except for the corrected Stone price index. However, the correlation between the two price indices is as high as 0.99 and the estimates in (2) under both product classifications are virtually

---

[19] Price elasticities are computed as the compensated price elasticities as in Chalfant (1987). Alston, Foster, and Green (1994) show that formulas in Chalfant (1987) are reasonable approximations for the exact elasticities derived from the AIDS model using the original price index.

identical. Therefore, we report only the expenditure equation in Table 3 based on the first

product classification.

Table 3. The U.S. expenditure on olive oil

Dependent variable:	log of U.S. total expenditure on olive oil		
Independent variables:			
Corrected Stone price index for all olive oils	0.730 (0.020)	Log of # of accumulated articles, up to 12 months ago	0.153 (0.009)
Log of personal income	1.013 (0.035)	Log of # of articles, in the past 12 months	0.038 (0.013)
Log of CPI	-0.844 (0.038)	Log of cheese import	0.105 (0.008)
Log of canola oil price	0.100 (0.017)		

Note: Standard errors are in parentheses.

We compute the price elasticity of U.S. demand for all olive oils based on the estimates

in Table 3. Specifically, if we aggregate all olive oils into a single product using the Divisia

volume index, the corresponding price elasticity of demand for all olive oils is -0.270(=0.730-

1).[20] Note that the demand for olive oil, as a single product, is less elastic than the demand for

individual types of olive oil due to the substitution within olive oil varieties. To put the

magnitude of the price response in perspective, Yen, Kan, and Su (2002) report that the price

elasticity of demand for cooking oil in the United States is about -0.5. Therefore, the U.S.

demand for olive oil is less sensitive to price changes than major vegetable oils as a single

product.

We use the estimates in Table 3 along with the expenditure elasticities in Table 2 to

calculate other elasticities of the U.S. demand for olive oils as reported in Table 4. Specifically,

the elasticities in Table 4 are the product of the expenditure elasticities in Table 2 and the

---

[20] The U.S. expenditure on olive oil can be characterized by the product of the Stone price index and the Divisia volume index.

estimated coefficients for the variables of interest in Table 3. Focusing on income elasticities of

demand, we find that each type of olive oil is a normal good, with the income elasticities positive

and statistically significant. The income elasticities of demand for virgin olive oils are all above

one, and the income effect is even larger for virgin olive oil imported from non-EU countries.

Table 4. Other elasticities of U.S. demand for olive oils

Elasticities with respect to	Product classification I		
	EU/Virgin	**Non-EU/Virgin**	**Non-Virgin**
Income	1.149 (0.020)	1.427 (0.032)	0.514 (0.053)
Canola oil price	0.114 (0.020)	0.141 (0.025)	0.051 (0.009)
# of accumulated articles, up to 12 months ago	0.174 (0.010)	0.216 (0.013)	0.078 (0.005)
# of articles, in the past 12 months	0.043 (0.015)	0.054 (0.019)	0.019 (0.007)
Cheese import	0.120 (0.009)	0.149 (0.011)	0.054 (0.004)
	Product classification II		
	Italy/Virgin	**Non-Italy/Virgin**	**Non-Virgin**
Income	1.198 (0.023)	1.159 (0.025)	0.670 (0.057)
Canola oil price	0.106 (0.020)	0.103 (0.020)	0.060 (0.011)
# of accumulated articles, up to 12 months ago	0.171 (0.011)	0.166 (0.010)	0.096 (0.006)
# of articles, in the past 12 months	0.038 (0.015)	0.037 (0.015)	0.021 (0.008)
Cheese import	0.126 (0.009)	0.122 (0.009)	0.070 (0.005)

Note: The elasticities are derived as the associated coefficients in the expenditure equation multiplied by the expenditure elasticities of demand in the AIDS systems. Standard errors are in parentheses.

We also find in Table 4 that canola oil substitutes with olive oil. Specifically, the cross-price elasticity is statistically significant, but the magnitude is below 0.15 for all olive oil varieties. In general, this cross-price elasticity between olive oils and canola oil is substantially lower than the cross-price elasticities within different types of olive oils (see off-diagonals of Table 2). This finding is consistent with our observation that olive oil is a specialty vegetable oil and it has no close substitutes among ordinary vegetable oils (recall Figure 1).

Importantly, we find that news articles about the healthiness or culinary benefits of olive oil contribute significantly to U.S. rising demand for olive oils. In particular, the publications stimulate more demand for olive oil through both channels. First, the accumulation of new articles makes consumers gradually aware of the good attributes of olive oil. Second, recent publications tend to remind consumers about the healthiness or culinary benefits of olive oil and stimulate demand for a limited period of time. We also find that the news reports promote the demand for virgin oils more than that for non-virgin oils. Given the stock of articles and the value of U.S. import of olive oils as of 2012, 100 more articles on olive oil would increase the value of U.S. annual import of olive oils by about $9.8 million through the reminder effect and by about $1.4 million through the accumulated knowledge effect.

Finally, we find that Americans' increasing appetite for the Mediterranean diet more generally has driven part of the expansion of U.S. olive oil demand. Variations in U.S. import of Italian-style cheeses, which we use as a proxy for growing acceptance of Mediterranean foods, significantly affect the U.S. import of olive oils.

4.2. The sensitivity analysis

The assumption that the expenditure on the foods of interest is separable from the overall consumer budget is a longstanding caveat in the food demand literature. The assumption

facilitates the derivation of a demand system, at the expense of restricting substitution patterns between foods inside and outside of the group of interest (Moschini, Moro, and Green, 1994). We check the separability assumption by fitting an incomplete demand system (LaFrance and Hanemann, 1989), in which the demand for olive oil is directly explained by the prices of olive oils, personal income, and other shifters. Specifically, we adopt a linear specification and impose the Marshallian symmetry by restricting parameters and homogeneity by deflating all nominal variables by CPIs.[21]

The results from the incomplete demand system suggest that the income effects are robust to the choice of demand system. In particular, all olive oils have positive income elasticities and virgin olive oils have income elasticities above one. The own-price elasticities of demand for individual types of olive oils are estimated to be around -0.3, which is the price elasticity of demand for all olive oils in the complete demand system. This result follows because some types of olive oils are found to be complements (although statistically insignificant) under the incomplete demand system. Therefore, the price elasticities for individual types are not significantly larger than the price elasticity for olive oil as a single product. The impacts of demand shifters are consistent with the results from the complete demand systems. In particular, we confirm that the expansion of the U.S. market for olive oil is attributable to the rising awareness of the healthiness and culinary benefits of olive oils and the spread of the Mediterranean diet in general. Further, we find that news articles on the healthiness or culinary benefits of olive oil promote the demand for olive oils primarily in the market for virgin oils.

5. Conclusions

---

[21] We use the Marshallian symmetry to approximate the Hicksian symmetry because the changes in olive oil prices have negligible impacts on U.S. personal income due to the tiny expenditure share of olive oil.

The market for olive oil in the United States has tripled over the past two decades. The new market opportunity and related quality issues have provoked increased interest in olive oil production and policy debate in the United States.

In this article, we contribute to the better understanding of the U.S. olive oil market by investigating key determinants of the demand for olive oils. Using data from U.S. customs, we find that the demand for all olive oil is inelastic in the United States (with an own price elasticity around -0.3). However, olive oils of different quality and countries of export are highly substitutable and the own price elasticity for each category of olive oil ranges from -0.4 to -1.3. We also show that virgin olive oil has an income elasticity above one. Furthermore, we find that the substitutability within different types of olive oils is much higher than that between olive oil and other vegetable oils.

Importantly, we find that news reports on the healthiness or culinary benefits of olive oil and Americans' growing appetite for a Mediterranean diet contribute to the growth of the olive oil market in the United States. These results illustrate that healthiness and related food attributes are important drivers of the dietary changes in the United States. Our results have laid foundations for future investigations of the emerging olive oil markets outside of the Mediterranean region.

Accurate estimates of demand parameters are critical to measuring and projecting impacts of domestic and trade policy options. This article provides the first econometric estimates for olive oil in the United States. Combining the current results with supply side information, future research can begin to assess implications of potential U.S. trade policy or quality regulations in the olive oil market.

In addition, olives and olive oil can be important contributors to economic development of agriculture in the rural areas of the Middle East and North Africa. We show that olive oil shipped directly from these countries has grown, but still trades at a price discount. We show that olive oil generally and virgin oil specifically has gained from media attention and this attention could be used to benefit high-quality exporters from developing countries. Improving quality and reputation in the new consumption markets could increase the returns to olive farms, oil processors, and trading firms.

References

Alston, J. M., Foster, K. A., and Green, R. D. (1994). Estimating elasticities with the linear approximate almost ideal demand system: some Monte Carlo results. *The Review of Economics and Statistics*, 351-356.

Butler, J. (2012). European Commission asked to act on threat of U.S. 'trade barriers.' *The Olive Oil Times*. http://www.oliveoiltimes.com/olive-oil-business/europe/european-commission-asked-to-act/30322, November 2, 2012.

Chalfant, J. A. (1987). A globally flexible, almost ideal demand system. *Journal of Business and Economic Statistics*, *5*(2), 233-242.

Chern, W. S., Loehman, E. T., and Yen, S. T. (1995). Information, health risk beliefs, and the demand for fats and oils. *The Review of Economics and Statistics*, 555-564.

Deaton, A., and Muellbauer, J. (1980). *Economics and consumer behavior*. Cambridge university press.

Dhar, T., Chavas, J. P., and Gould, B. W. (2003). An empirical assessment of endogeneity issues in demand analysis for differentiated products. *American Journal of Agricultural Economics*, *85*(3), 605-617.

Dickey, D. A., and Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, *74*(366a), 427-431.

Estruch, Ramón, Emilio Ros, Jordi Salas-Salvadó, Maria-Isabel Covas, Dolores Corella, Fernando Arós, Enrique Gómez-Gracia et al. (2013). Primary prevention of cardiovascular disease with a Mediterranean diet. *New England Journal of Medicine.*

International Olive Council. (2011). Trade standard applying to olive oils and olive-pomace oils. COI/T.15/NC No 3/Rev. 6, November 2011.

Kaabia, M. B., Angulo, A. M., and Gil, J. M. (2001). Health information and the demand for meat in Spain. *European Review of Agricultural Economics*, *28*(4), 499-517.

Kolata, G. (2013). Mediterranean diet shown to ward off heart attack and stroke. *The New York Times*. http://www.nytimes.com/2013/02/26/health/mediterranean-diet-can-cut-heart-disease-study-finds.html?pagewanted=alland_r=0 , February 26, 2013.

LaFrance, J. T. (1991). When Is Expenditure" Exogenous" in Separable Demand Models? *Western Journal of Agricultural Economics*, 49-62.

LaFrance, J. T., and Hanemann, W. M. (1989). The dual structure of incomplete demand systems. *American Journal of Agricultural Economics*, *71*(2), 262-274.

Mili, S. (1996). *Organización de mercados y estrategias empresariales en el subsector del aceite de oliva*. Ministry of Agriculture, Fisheries and Food, Publishing Services, Madrid, p. 219-232.

Menapace, L., Colson, G., Grebitus, C., and Facendola, M. (2011). Consumers' preferences for geographical origin labels: evidence from the Canadian olive oil market. *European Review of Agricultural Economics*, *38*(2), 193-212.

Moschini, G. (1995). Units of measurement and the Stone index in demand system estimation. *American Journal of Agricultural Economics*, *77*(1), 63-68.

Moschini, G., Moro, D., and Green, R. D. (1994). Maintaining and testing separability in demand systems. *American Journal of Agricultural Economics*, *76*(1), 61-73.

Okrent, A. M., and Alston, J. M. (2011). Demand for Food in the United States. Monograph 48 The Giannini Foundation, University of California.

Owen, R. W., Giacosa, A., Hull, W. E., Haubner, R., Würtele, G., Spiegelhalder, B., and Bartsch, H. (2000). Olive-oil consumption and health: the possible role of antioxidants. *The Lancet oncology*, *1*(2), 107-112.

Pierani, P., and Rizzi, P. L. (1991). An econometric analysis of the olive oil market in Italy. *European Review of Agricultural Economics*, *18*(1), 37-60.

Sofi, F, Cesari, F., Abbate, R., Gensini, G.F., Casini, A. (2008). Adherence to Mediterranean diet and health status: meta-analysis. *British Medical Journal*, 337: a1344.

The Economist. (2012). Drizzle and drought. http://www.economist.com/node/21563304, September 22, 2012.

Thompson, W. (2004). Using elasticities from an almost ideal demand system? Watch out for group expenditure! *American Journal of Agricultural Economics*, *86*(4), 1108-1116.

Tiffin, R., and Arnoult, M. (2010). The demand for a healthy diet: estimating the almost ideal demand system with infrequency of purchase. *European Review of Agricultural Economics*, *37*(4), 501-521.

Tuck, K. L., and Hayball, P. J. (2002). Major phenolic compounds in olive oil: metabolism and health effects. *The Journal of Nutritional Biochemistry*, *13*(11), 636-644.

United States Department of Agriculture- Foreign Agricultural Service. Data file "Oliseeds" in the Downloadable Data sets, PSD Online.
http://www.fas.usda.gov/psdonline/psdDownload.aspx

United States Department of Agriculture- Agricultural Marketing Service. United States standards for grades of olive oil and olive-pomace oil.
http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3011889

United States International Trade Commission. (2012). Olive oil will be focus of new USITC study. http://www.usitc.gov/press_room/news_release/2012/er1001kk1.htm , October 1, 2012.

Wooldridge, J. M. (2002). *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press.

Yen, S. T., Kan, K., and Su, S. J. (2002). Household demand for fats and oils: two-step estimation of a censored demand system. *Applied Economics*, *34*(14), 1799-1806.

Appendix A

Table A. Data series and sources

Series	Source
U.S. import quantity of olive oils	U.S. Customs & Border Protection
U.S. import value of olive oils	U.S. Customs & Border Protection
U.S. import quantity of Italian-style cheese	U.S. Customs & Border Protection
U.S. import price of canola oil, computed as import value divided by import quantity	U.S. Customs & Border Protection
U.S. quarterly personal income	U.S. Bureau of Economic Analysis http://www.bea.gov/iTable/index_nipa.cfm
U.S. monthly population estimate	U.S. Census Bureau http://www.census.gov/popest/data/index.html
U.S. monthly Consumer Price Index, city averages for all urban consumers	U.S. Bureau of Labor Statistics http://www.bls.gov/cpi/#data
News articles on the health or culinary benefits of olive oil	News Bank http://www.newsbank.com/

Note: U.S. Customs & Border Protection data is available from USITC Interactive Tariff and Trade DataWeb at http://dataweb.usitc.gov/scripts/user_set.asp. The product codes for olive oil imports in the USITC database are: 1509102000, 1509104000, 1509902000, and 1509904000. U.S. quarterly personal income is transformed to monthly series using the method of the Federal Reserve Bank of St. Louis. http://research.stlouisfed.org/fred2/series/POP?rid=59andsoid=19

Appendix B

Table B. The statistical tests for unit roots and serial correlations

Test	Null Hypothesis	P value
Dickey-Fuller		
	Expenditure share of EU/Virgin contains unit root	0.00
	Expenditure share of Non-EU/Virgin contains unit root	0.00
	Expenditure share of Italy/Virgin contains unit root	0.00
	Expenditure share of Non-Italy/Virgin contains unit root	0.00
	Expenditure share of Non-Virgin contains unit root	0.00
	Log of olive oil expenditure contains unit root	0.00
Wooldridge		
	No first-order autocorrelation under the product classification I	0.13
	No first-order autocorrelation under the product classification II	0.36

Note: A deterministic trend is included in all Dickey-Fuller tests. The Wooldridge test is based on the specification in (1), without parameter restrictions. Product classification I is {EU/Virgin, Non-EU/Virgin, Non-Virgin}. Product classification II is {Italy/Virgin, Non-Italy/Virgin, Non-Virgin.

Appendix C

Table C. Hausman-Durbin-Wu test for U.S. import prices of olive oils

$$q_{kt} = \alpha_k + \beta_k y_t + \gamma_k p_{kt} + \delta_k p_{ct} + \phi_k cheese_t + \theta_k Kart_t + \sigma_k Rart_t + seasonality$$

Instrumental variables   Annual dummy variables based on marketing years

Null hypothesis   "U.S. import price is exogenous to U.S. import quantity"

	EU/Virgin	Non-EU/Virgin	Italy/Virgin	Non-Italy/Virgin	Non-Virgin
P-value	0.16	0.08	0.12	0.10	0.02

Note: Subscript *k* denotes a product within {EU/Virgin, Non-EU/Virgin, Italy/Virgin, Non-Italy/Virgin, and Non-Virgin}.

Appendix D

Table D. Estimated coefficients from the AIDS model with endogenous expenditure

The AIDS equations

Share of olive oil, of type	Product classification I		
	EU/Virgin	**Non-EU/Virgin**	**Non-Virgin**
Log of price of EU/Virgin	-0.072 (0.018)	0.005 (0.009)	0.067 (0.017)
Log of price of Non-EU/Virgin	0.026 (0.008)	-0.051 (0.008)	0.025 (0.009)
Log of price of Non-Virgin	-0.035 (0.016)	-0.006 (0.009)	0.041 (0.020)
Log of expenditure	0.081 (0.012)	0.052 (0.004)	-0.133 (0.014)
Time trend	0.001 (0.000)	0.000 (0.000)	-0.001 (0.000)
Constant	0.021 (0.040)	-0.152 (0.015)	1.131 (0.047)
	Product classification II		
Share of olive oil, of type	**Italy/Virgin**	**Non-Italy/Virgin**	**Non-Virgin**
Log of price of Italy/Virgin	-0.168 (0.019)	0.118 (0.014)	0.050 (0.016)
Log of price of Non-Italy/Virgin	0.113 (0.013)	-0.099 (0.017)	-0.014 (0.014)
Log of price of Non-Virgin	-0.007 (0.015)	-0.054 (0.014)	0.061 (0.020)
Log of expenditure	0.062 (0.009)	0.035 (0.007)	-0.097 (0.015)
Time trend	0.001 (0.000)	0.001 (0.000)	-0.001 (0.000)
Constant	0.015 (0.031)	-0.028 (0.025)	1.013 (0.049)

Note: Monthly dummy variables are included in the AIDS equations but omitted from the table for brevity. Standard errors are in parentheses.