The determinants of US olive oil imports

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Abstract

We investigate the determinants of US bilateral imports of olive oil and their dynamics from shocks in foreign supplies and changes in US olive oil demand, using an augmented sectoral gravity framework leading to equilibrium bilateral trade flows from olive oil exporters to the US market. The empirical specification uses a panel dataset at the HS-6 disaggregation level and two estimation techniques (PPML and Heckman), that account for zero trade flows, the extensive margin of trade and the potential censored distribution of exports with zero trade flows. We run Reset and HPC tests to qualify our results. On the supply side, exporters' capacity to export, multilateral trade resistance, and immigrants' networks into the US are strong determinants of the bilateral trade flows for both aggregate olive oil exports and for virgin olive oil exports, On the consumer side, US GDP, import unit value, and immigrant network effects are robust determinants of bilateral flows as well for aggregate and virgin olive oil trade flows. Migrants' stock, exporters' GDP and population, and total exports revenues increase the probability of an exporter entering the US market. Beyond the immigrant network effects, we could not find robust evidence of consumer behavior being influenced by popular press measures of the emergence of Mediterranean diet and olive oil, or measures of cultural globalization of US consumers.

Keywords: *Olive oil, Trade, Gravity equation, Migrant network.*

1. Introduction

Olive oil exports to the US have been increasing considerably for several decades. Trade flows have quadrupled in the last three decades (see Table 1). Numerous factors might explain this strong growth of olive oil trade between the US and the rest of the world, from factors influencing import demand and export supply of olive oil. On the demand side, beyond demographic changes, income growth, and price effects, olive oil is known for its health benefits, and it is part of the increasingly popular Mediterranean diet. The presence of large immigrant populations of Mediterranean origin in the US may have popularized the use of olive oil in that cuisine. The composition of olive oil imports has also evolved over time, towards higher quality imports of virgin olive oil and away from pomace, and more diversified sources. New export suppliers have emerged and entered the growing US market. Network effects may have helped establishing olive oil business networks through Mediterranean migrants as it has happened in other industries (Combes *et al*., 2005; Rauch, 1999). The extensive margin of trade (new exporters) is another interesting aspect to investigate to explain the rapid evolution of these US imports of olive oil.

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Despite its economic importance (nearly $1.3 billion in 2019), international trade of olive oil between the US and the rest of the world has received limited attention. Xiong *et al*. (2014) estimated US demand for olive oil including the role of popular diet, distinguishing three olive oil types. Ronen (2017) investigated global aggregate olive oil trade looking at the impact of nontariff measures, using a gravity-like framework. Hammami and Beghin (2021) analyze the impact of recent US retaliatory tariffs imposed on olive oil imports sourced in Spain. Our study contributes to the existing literature on olive oil trade, focusing on the US, the largest importer of olive oil, with imports predominantly sourced from the Mediterranean basin. It examines the threefold increase in import volumes from the early 1990s to 2019. There patterns precede important recent shocks but appear to have persisted despite of them. Recent shocks include the US retaliatory tariff imposed on individually packaged Spanish olive oil imports in 2019-2021, trade disruptions caused by COVID-19, and recent geopolitical instabilities.

We investigate US imports of olive oil considering demand and supply determinants and elements of extensive margins using an augmented gravity-equation equilibrium framework. The framework incorporates usual demand determinants (prices, demographics, and income), the evolving sophistication of US diet, bilateral and multilateral trade costs, and supply elements explaining the intensive and extensive margins of trade from various sourcing countries, into an equilibrium framework at the sectoral level (Yotov *et al*., 2016). The framework leads to an empirical specification applied to a panel dataset at a disaggregated HS-4 and 6 levels for olive oil products, and with two estimation techniques, which account for the large number of zeros, the extensive margin of trade, and the potentially censored distribution of bilateral trade flows.

On the supply side, we find that exporters' capacity to export, multilateral trade resistance, and immigrants' networks from olive-oil exporting countries into the US are strong determinants of the bilateral trade flows for both aggregate olive oil exports and for virgin olive oil exports. On the demand side, we find that US aggregate income, the import unit value, and immigrant network effects from olive-oil exporting countries are robust determinants of bilateral flows as well for aggregate and virgin olive oil trade flows. Regarding the extensive margin of trade, migrants' stock, exporters' GDP and population, and total exports revenues increase the probability of an exporter entering the US market. Beyond the important result on migrant networks, we did not find robust evidence of systematic influences on US consumer behavior by variables proxy-ing for the popularity of Mediterranean diet, or increasing popularity of olive oil, or measuring cultural globalization of US consumers.

The following sections provide some background information on the olive oil sector in the US, and then describe the key elements of the conceptual equilibrium framework of the gravity equation with the relevant specifics of the investigation. Estimation techniques and data description follow. Findings are presented in the last section before conclusions. A Review Appendix available from the authors provides further figures, econometric runs and tests.

2. Background on the US olive oil market and olive oil exporters

2.1. *The evolution of the US olive oil market*

Table 1 shows US olive oil production supply and disappearance and documents the phenomenal growth of the market. Olive oil consumption has quadrupled since 1990. As a result, the US has become the world largest importer of olive oil (roughly 10% of world production). More than 90% of its domestic consumption is imported.

Cultural elements may have influenced the consumption of olive oil by US consumers. First, interest in and knowledge about the benefits from olive oil, Mediterranean diet, and healthy diet have been continuously increasing among Americans (Pubmed.gov, 2020). Cultural globalization may also have facilitated the move away from the Anglo-Saxon diet to a more Mediterranean one. Deeper influences may have come through cultural network effects with rising populations of immigrants from Mediterra-

Table 1 - US olive oil Production, Supply and Disappearance in 1000 tons.

Attribute	*1990/1991*	*1995/1996*	*2000/2001*	*2005/2006*	*2010/2011*	*2015/2016*	*2016/2017*	*2017/2018*	*2018/2019*	*2019/2020*
Production	1	1	0	2	5	14	15	16	16	16
Imports	100	114	212	242	290	330	316	322	355	390
Total Supply	101	115	212	244	295	344	331	338	371	406
Exports	4	11	4	9	4	8	13	12	7	6
Consumption	97	104	208	235	291	336	318	326	364	400
Distribution	101	115	212	244	295	344	331	338	371	406

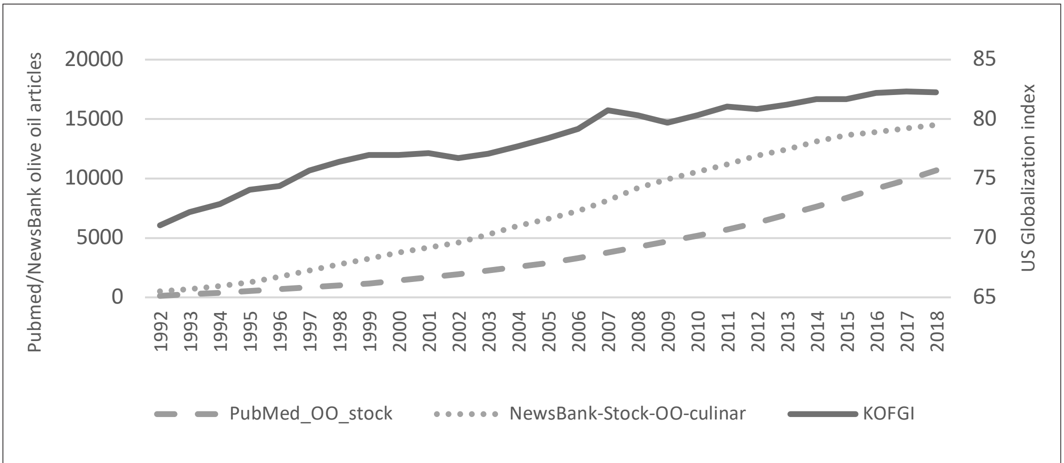
Source: USDA PS&D, 2020.

nean countries in which olive oil is paramount in the diet. For example, the increasing emigration out of Spain towards the US has been documented (Bermudez and Brey, 2017). These populations can both influence US consumers' preferences and facilitate business links back home to export to the US. We hypothesize that migrant networks may have had influenced the adoption, level of consumption, and availability of olive oil in the US and its sourcing.

To capture the growing stock of health knowledge on olive oil, we rely on Pubmed.gov to compute an index of the number of published academic refereed articles in medical journals mentioning key search terms (olive oil). This index allows for a longer and less biased series than those based on internet data[1]. In Figure 1, olive oil-related indices in the US exhibit growth patterns, as the number of medical and news articles mentioning olive oil, as well as the globalization index in the US, consistently increase since 1990.

We conjecture that the popularity of olive oil could come from cultural influence of migrants from olive-oil producing countries. Figure 2 shows the stock of migrants from olive-oil exporting countries, along with the imports from the same countries. The stock of migrants suggests a strong correlation with the increasing olive oil imports. The bilateral nature of the

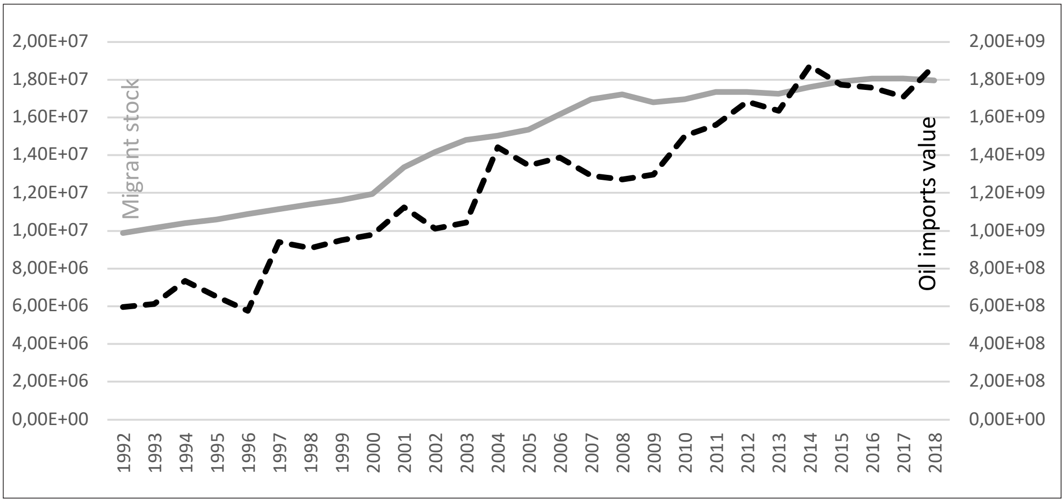
Figure 1 - Evolution of olive oil-related health, culinary and cultural indices.



Source: Pubmed.gov, 2020; kof.ethz.ch, 2020; Gygli et al., 2019; NewsBank, 2020.

[1] In the econometric estimation, we also use a related index reflecting the stock of popular press articles on Mediterranean diet using https://www.newsbank.com/ as in Xiong *et al*.

Figure 2 - Migrant stock from olive oil exporters & olive oil imports in the US.



Source: US Trade Census, 2020; Office of Immigration Statistics' (OIS), 2020.

migrant panel data provides more variation than the number-of-articles variable which only varies over time.

2.2. *Patterns of US imports of olive oil*

The olive oil market in the US can be differentiated into two main categories: virgin and non-virgin oils. Virgin oil is a higher quality product, since during this process olives have been simply pressed with no heat or chemicals involved. Virgin oils have two sub-categories defined by free acidity: extra virgin defined by free acidity of less than 0.8% and virgin olive oil with free acidity between 0.8% and 2%. These oils are pure and not refined.

All other olive oils, heat or chemically treated, are considered non-virgin and can be sometimes mixed with some virgin oil and simply called olive oil with free acidity above 2%. Olive oil extracted by chemical process is called pomace and is the lowest quality product. There are other subcategories of virgin olive oil (first cold pressed, cold pressed, and organic) (IOC, 2020).

The "Olive Oil & Its Fractions" category imported to the USA under the HS code 1509, has the largest average share of consumption of more than 90% of all olive oils imported and consumed in the US. The remaining share is the "Olive-residue Oil & Blends" category under HS code 1510 (edible and non-edible). The "Olive Oil & Its Fractions" category (HS code 1509) divides into "Virgin olive oil/fractions" category (HS code 150910 and "Refined olive oil / fractions" (HS code 150990) category[2]. The virgin olive oil (HS 150910) includes extra-virgin, labelled and organic of a superior quality than the refined one. Since the early 1990's, the share of virgin olive oil has been increasing from 35% to reach 80% of olive oil imports. This increase reflects both the rising consumption of olive oil and the progression towards higher-quality olive oil consumed in the US. The global economic crisis of 2008-09 temporally reset the clock on this evolution as shown in Figures 3.a and 3.b; trends are clear.

Figure 4 shows the evolution through time of US imports for virgin olive oil by import source. EU sources dominate (Spain and Italy), The

[2] HS 1509: Olive oil and its fractions, whether or not refined, but not chemically modified; HS 150910: Olive Oil and Its Fractions, Virgin, Not Chemically Modified; HS 150990: Olive Oil and Its Fractions, Refined But Not Chemically Modified. HS 1510: Other Oils and their fractions, obtained solely from olives, whether or not refined, but not chemically modified, including blends of these oils or fractions with oils or fractions of heading 1509.

Figure 3.a - Evolution of import shares: Olive oil and Residual (1992-2019).

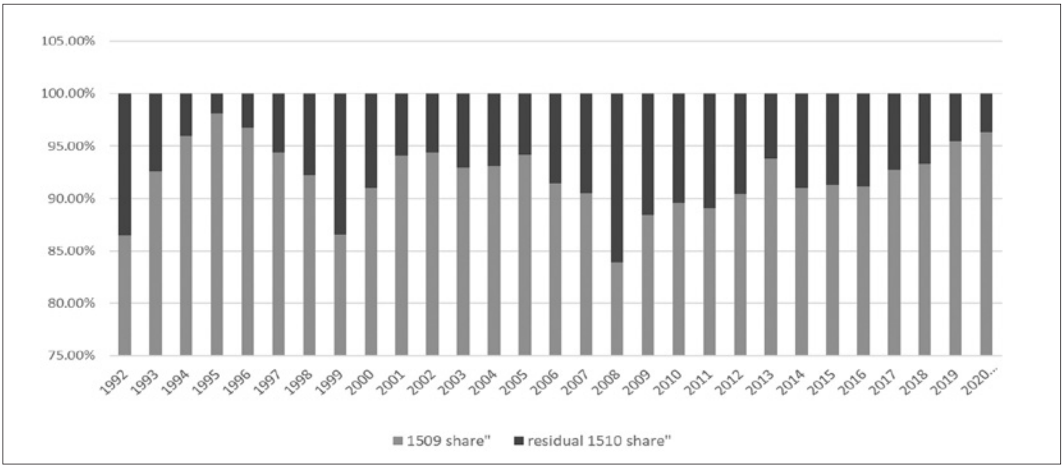
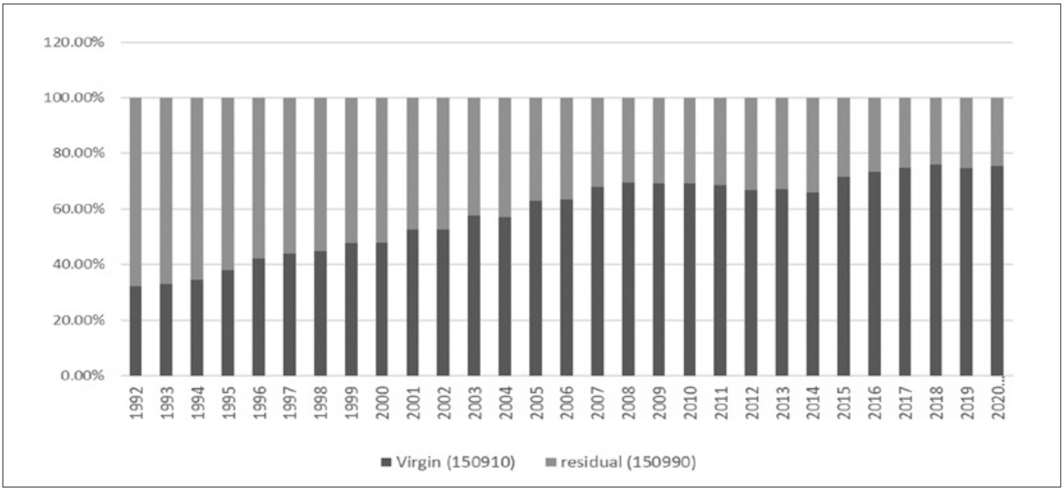


Figure 3.b - Evolution of import shares: Virgin and Refined (1992-2020).



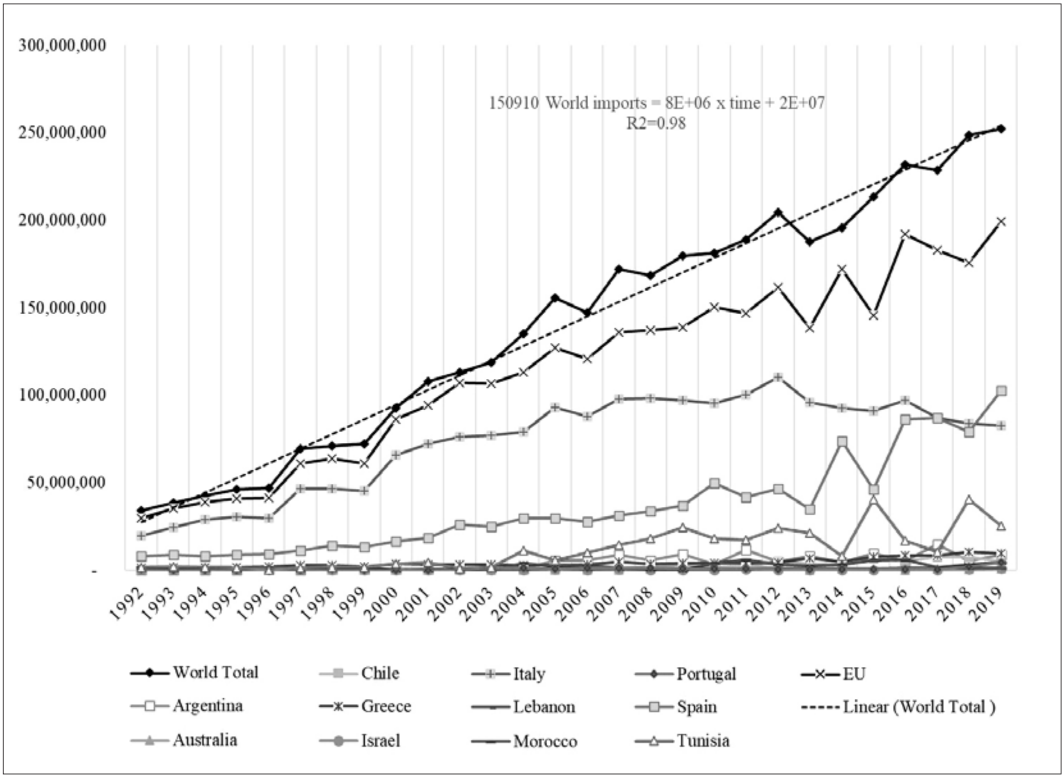
Source: US Trade Census, 2020.

importance of non-EU Mediterranean sources (Tunisia, Morocco) is rising, and a competitive fringe exists with Argentina, Israel, Lebanon, Chile, and Australia.

Most of the virgin olive oil imported to the US is from Italy and Spain. Spain overtook Italy in 2018. The rest of the countries exporting to the US have remained small exporters but with growing quantities exported. They provide a competitive fringe to the established exporters. Tunisia has increased its exports to the US the most, since 2004, approaching Spain exports in 2015, and remains the largest exporter within the fringe.

Argentina has had a noticeable increase since 2005 and is now the 4th largest virgin olive oil exporter to the US. Olive production for olive oil exhibits stochastic yields with "good and bad" years resulting in annual variations of production even for established exporters. Inventories partially mitigate these variations. Variations in export supply are also reflected by significant variations in import unit values. On average, import unit values have been rising slightly above inflation rates. Import unit values vary among exporters, indicating differences in quality and competitiveness. Italian, Israeli, and Argentini-

Figure 4 - Evolution of US virgin olive oil (150910) imports by country of origin (1992-2019).



Source: US Trade Census, 2020.

an unit values have increased more rapidly than others (see Review Appendix Figure 1.A).

US imports of refined olive oil have been on a decreasing trend for most exporters (not shown) as consumers upgraded to virgin olive oil. Italy and Spain are major exporters of refined oil, ahead of the others (fringe). The fringe of other exporters still has Tunisia as the third largest source competing with Turkey and Morocco. The unit value of refined olive oil is also increasing. However, the dispersion across sources is smaller compared to the normalized unit values of virgin olive oil (see Review Appendix Figure 2.A).

2.3. *Supply shocks in World olive oil markets*

Various supply shocks and changes interact with US demand of olive oil. Producing countries, endowed with a specific Mediterranean climate, compete to supply the world market, including the US. Profit-maximizing firms in these countries' supply chains compete and adapt to changing market conditions. New entries and production techniques have put pressure on average unit values. Spain, as an example, invested hugely on reforming olive oil production and opted for an intensive production since the 1960's. Nowadays, Spain supplies almost half of world production (46%) (Guerrero, 2014).

Italy and Greece relied both on their historical reputations and their authentic ancient know-how to signal their quality. Italy imports large amounts of Spanish oil, which allegedly find their way back on the world market. However, there has been a history of olive oil fraud concurrently, wherein false labels—whether related to quality or product source—are employed to generate increased profits (Da Silveira *et al*., 2017; Bimbo *et al*., 2019; Yan *et al*., 2020; Casadei *et al*., 2021). With the development of digital marketing strategies and globalization, olive oil producers are going up market and non-traditional producers are entering the international market. The resulting glut in the world supply of olive oil pushes producers to differentiate their product for a higher quality (IOC, 2020; Milli, 2006; USDA PS&D, 2020). The increasing and now dominant share of virgin olive oil in US imports reflects this fact.

Finally, olive oil production has a stochastic yield due to environmental and agronomic shocks. Weather, pathology, and physiological state of the trees impact its yearly production. Olive trees are biennial trees that have alternate yearly production. One year above the average production and one year below. We later investigate this potential variability of yield, although unit values of traded olive oil reflect that variability to a great extent.

2.4. *Evidence on the evolution and sophistication of consumer demand*

Consumers around the world, including in the US, have been increasingly concerned about the quality of food they purchase (IFIC, 2018). Many studies have investigated the relation between health and nutrition information and food demand. Early research about health and nutrition factors has found evidence of diversion of US demand from food containing cholesterol and heavy fats (Brown & Schrader, 1990; and Chern *et al*., 1995). Other studies have approached health information and demand from the experimental and behavioral perspective (e.g., Hilger *et al*., 2011).

Diet trends have been emerging with various news coverage and success, such as keto, vegan, and Mediterranean diet, among others. The Mediterranean diet has spread in the industrialized world from its origin in the Mediterranean basin. Alexandratos (2006) and Regmi *et al*. (2004) investigated this rise of the Mediterranean diet and related it to globalization and income growth. Trends of global and US food consumption determinants are examined. Regmi *et al*. (2004) analyzed trade data to determine changing diets phenomenon's effect on Mediterranean diet products' trade.

Studies of olive oil demand in North America have been scarce (Del Giudice *et al*., 2015). Xiong *et al*. (2014) estimated US demand for olive-oil differentiated products using the AIDS model and accounting for the impact of information on Mediterranean diet. They find that both the stock and number of press articles discussing olive oil and health are positively related to the level of olive oil imports. They aggregate all olive oils imports into three aggregate categories. Menapace *et al*. (2011) study olive demand in Canada through a survey that demonstrated the significance of geographical indication and certification of origin Label.

Main studies on olive oil focus on Europe. Many are surveys and experiments (Karipidis *et al*., 2005; Kalogeras *et al*., 2009; Bernabéu & M. Díaz, 2016; Cacchiarelli *et al*., 2016; Carbone *et al*., 2018; and Scarpa & Del Giudice, 2004). Relevant to our analysis, in the context of a net-importing country, Kavallari *et al*. (2011) investigate the structure of import demand of Germany and UK for olive oil from southern European producers. That study itself has been based on Vlontzos and Duquenne (2008) on Greek olive oil potential in the international market. Finally, Garcia Álvarez-Coque and Martí Selva (2006) use a gravity model to estimate euro-Mediterranean fruits and vegetable trade flows.

3. Model

The gravity equation approach to bilateral trade is widely popular among trade economists, despite its drawbacks being overly structured with symmetric trade costs, fixed endowment approach to supply and its normalization of price limited to cross-section data (Yotov *et al*., 2016; Baldwin and Taglioni, 2006). These assumptions are relaxed here.

Methods of estimation have evolved greatly to address the presence of zero bilateral trade flow, the extensive margin to trade, and typical estimation mistakes biasing results. Baldwin and Talglioni (2006) identified three principal mistakes of gravity model's applications in the literature, when multilateral trade resistance terms are omitted and are correlated with error terms, leading to bias; when bilateral trade flow volumes are wrongly deflated by a common deflator, and when computing the wrong log-averaging of the bilateral trade flow volumes. The authors proposed several time-varying and unvarying dummies as an attempt to adjust gravity regression mistakes.

More complex issues with gravity models such as the extensive margin of trade have been addressed as well. Several authors such as (Melitz, 2003) have elaborated the extensive margin of trade, beyond a simple Heckman sample selection process explaining the decision to trade or not between two countries. Firms are heterogeneous and the most productive firms enter new markets at the extensive margin. Gould (1994), Rauch (1999), and Combes *et al*. (2005) focus on network effects on trade for differentiated products. Our approach relies on a simple sample-selection approach to the extensive margin and incorporates network effects in both margins.

3.1. *The sectoral gravity model*

We consider only a single destination j (j=us) as in Kavallari *et al*. (2010). Products are differentiated by country of origin. The demand in the destination country (here the US indicated by the subscript us), is obtained from maximizing a CES-utility function, with utility derived from consuming products differentiated by origin (all exporters of olive oil). The setup extends to a sectoral approach from which we abstract here to simplify the presentation. The

$$\left\{\sum_i \; a_i^{\frac{1-\sigma}{\sigma}} c_{ius}^{\frac{\sigma-1}{\sigma}}\right\}^{\frac{\sigma}{\sigma-1}},$$

subject to the following budget constraint for a set expenditure E,

$$\sum_i p_{ius} c_{ius} = E_{us} \,,$$

where, σ>1 is the elasticity of substitution between goods. The exogenous taste parameter a_i is the CES preference parameter, which will be instrumental later to incorporate the impact of diet information.

The consumption of varieties from country i is given by c_{ius}. Total expenditure (E_{us}) measured at delivered prices ($p_{ius} = pi\ t_{ius}$) defined as a function of factory-gate prices in country of origin (p_i) and bilateral trade costs markup (1+trade cost) from i to (t_{ius} >1).

Utility maximization under a budget constraint leads to the demand for variety i:

$$x_{ius} = \left(\frac{a_i p_i t_{ius}}{P_{us}}\right)^{(1-\sigma)} E_{us} \,, \qquad (1)$$

where x_{ius} is the trade flow in value from origin i to the US, and P_{us} denotes a CES consumer price index or "inward multilateral resistance", capturing the ease of market access into the US:

$$P_{us} = [\textstyle\sum_i \; (a_i p_i t_{ius})^{1-\sigma}]^{\frac{1}{1-\sigma}} \,. \qquad (2)$$

Next, a market clearing condition for each exported good equates production to the sum of demands in all destination markets, including domestic demand. The equilibrium condition leads to exporters' multi-resistance terms. The equilibrium condition assumes that the shipped quantities "melt" on the way to their destinations j by an amount equivalent to the trade cost:

$$Y_i = p_i Q_i = \textstyle\sum_j \; x_{ij} = \sum_j \; \left(\frac{a_i p_i t_{ij}}{P_j}\right)^{1-\sigma} E_j \,. \quad (3)$$

It is equal to factory-gate prices p_i multiplied by Q_i supply of the given product in exporter i before melting of the iceberg occurs (representing trade cost). Bilateral trade cost is an iceberg cost. For US consumers to receive x_{ius}, exporters have to send $x_{ius}\, t_{ius}$ with $t_{ius} > 1$. Buyers bear that extra-cost of x_{ius} (t_{ius}-1). Equation (3) presents the determinants of the equilibrium trade flow between countries i and j. The term

$$(a_i p_i)^{1-\sigma} = \frac{Y_i}{\Pi_i} \,,$$

is used to eliminate the factory price in the equilibrium condition. The price index Π_i is given by:

$$\Pi_i \equiv \textstyle\sum_j \; \left(t_{ij}/P_j\right)^{1-\sigma} E_j \,, \qquad (4)$$

which is the "outward multilateral resistance" that shows exporter i's ease of market access into all j countries (Baldwin and Taglioni, 2006). Substituting (3) and (4) in (1) yields:

$$x_{ius} = \frac{Y_i E_{us}}{\Pi_i}\left(\frac{t_{ius}}{P_{us}}\right)^{1-\sigma}, \qquad (5)$$

where $Y_i E_{jus}$ illustrates the "size term," and

$$\frac{1}{\Pi_i}\left(\frac{t_{ius}}{P_{us}}\right)^{1-\sigma}$$

is the "trade cost term." In our sectoral application, we assume that Y_i represents the capacity to export olive oil by country i. Then for any exporter i the ratio

$$\frac{1}{\Pi_i}\left(\frac{t_{ius}}{P_{us}}\right)^{1-\sigma}$$

represents the trade cost of the US market relative to all destination markets served by that exporter. It can be shown that this ratio varies monotonically with the ratio of the US import unit value for that exporter and the average real import unit value of that exporter to all destinations. We use this characteristic in our empirical strategy.

3.2. *Empirical strategy (estimation approach and empirical specification)*

As shown in section 2, the set of countries exporting olive oil to the US has been changing over time. Some countries entered the market several years ago, such as Australia, Brazil, Algeria, Peru, Slovenia, among others. When a competitor has not yet entered or chooses to exit the US market for a given year, its trade volume will be taking the value of zero. In general, to accommodate zeroes, many investigations use PPML, which allows to include zeroes as part of the intensive margin of trade by taking the exponent of equation (5) and the logarithm of continuous variables on the right-hand-side of the equation.

One can add an extensive margin to this which in PPML is confounded with the intensive margin and does not address potential selection into exporting to a destination market and the potential censoring in zero observations. PPML estimates are consistent under heteroskedasticity and the approach provides a natural solution to mechanically handle zero values of the dependent variables and provides a robust covariance matrix estimator (Santos Silva and Tenreyro, 2006).

We address the extensive margin of trade using Heckman sample selection, which accounts for the censoring of the latent variable representing the decision to trade or not through its first-stage Probit. We do not account for the second element of extensive margin of heterogeneous firms noted above. For completeness we also provide truncated OLS estimates in the Review Appendix, using the strictly positive observations in the dataset. We also run a Probit of the probability to export by countries over time, to gauge the fit of the selection equation in the Heckman model.

In alignment with Kavallari *et al*. (2010), our gravity equation focuses on a sole importer, specifically the US, utilizing an imbalanced panel. This choice involves a trade-off, resulting in reduced variation in the destination country (solely over time). However, it facilitates the acquisition of results specific to the US, as opposed to estimates reflecting a diverse panel of countries.

For Statistical tests, first, we run a Ramsey RESET test to check if the models exhibit evidence of misspecification. Second, we use the HPC test of Santos Silva *et al*. (2015) to choose which of PPML or Heckman fits our olive oil data the best. The HPC test discriminates between two competing models to fit data with many zeros. The test compares "two-process models" like Heckman to a simpler 1-process model accommodating zeros without explicit extensive margin like the PPML approach.

Specification and variable proxies

Since we have panel data (1992-2018) for 21 exporters, we add a time subscript to our specification. Each olive oil product k imported by the *US* at year t from exporter i, has the following trade flow equation:

$$X_{iUStk} = \frac{Y_{it}E_{US,t}}{\Pi_{ikt}}\left(\frac{t_{iUStk}}{P_{USkt}}\right)^{1-\sigma}. \tag{6}$$

We also make use of the ratio indicated in footnote 3. Since both the US import unit value and the exporter's average import unit value are time varying, our combined variable

$$\frac{1}{\pi_{it}}\left(\frac{p_{it}\ t_{iust}}{P_{ust}}\right)^{1-\sigma}$$

is obviously time varying. For product k, it is proxy-ed by the ratio

$$\frac{UV_{i,US,t,k}}{avgUV_{i,t,k}}$$

where $avgUV_{i,t,k}$ is the average unit value of product k over all destinations served by exporter i. It plays the role of outward trade resistance measure since it includes all the t_{ij} trade costs for all j markets served by exporter i.

Further, we use the time-varying capacity to export olive oil by exporters to approximate output y_{it}. Variable $Tot\_exports_{i,t,k}$ is exporter i's total exports of olive oil k to the world in year t. It is a solid proxy for exporter i's production and capacity to export olive oil k. We choose this variable as olive production data from FAO are incomplete for several countries and do not disaggregate olive oil types. The smoothing role of inventories is implicit in total exports, without having to model it explicitly. We also address potential endogeneity of supply determinants using a series of exporter fixed effects to address some of the potential endogeneity issues coming from omitted variables. This is not implementable on the importer side since we only have a single destination in the trade flow data (j=USA).

On the demand side of equation (6), we already have the import unit value $UV_{i,t,k}$ and then we use 2010-price constant US GDP, $realGDP_{US,t}$ as a proxy for consumers' income. The latter income measure includes demographic change affecting US GDP.

Regarding trade-flow determinants related to diet adoption, cultural influences, and market penetration, we first rely on immigration networks (stock of migrants from olive oil exporting countries). Immigration and tourism are important factors having network effects that can affect food trade flows (Kavallari *et al*., 2011). Rauch and Trindade (2002) found that the share of ethnic Chinese populations as immigrants in a country affects bilateral trade of that country with China. This is consistent with earlier investigations (Gould (1994) and Rauch (1999)). Rauch (1999) used proximity variables such as distances –this was prior to the CEPII database availability on distance. We investigate this geographic proximity relying on the geodist database of CEPII. Following Gould (1994) and Combes *et al*. (2005), we look at migrant networks coming to the US. The immigration data are collected from the Office of Immigration Statistics' (OIS) yearbooks of immigration statistics 1996-2019. We use tables of Persons Obtaining Lawful Permanent Resident Status by Region and Country of Birth (Office of Immigration Statistics, 2021). In the Heckman model with the extensive margin, we further investigate the role of migrants into the extensive margin. The latter would capture business network influences, rather than their cultural influence, of migrant networks from olive-oil producing countries.

We rely on established empirical strategies to incorporate the impact of health information and information on popular diets in demand systems. Variables capturing US consumer's demand sophistication are incorporated into a CES framework through preference parameter X in equation (1). Indices reflecting the sophistication of demand are as follows. First, we use the KOF index of cultural globalization which measures the degree of globalization of 122 countries over time based on economic, social, and political criteria on a 100-score scale for each country. The index was first introduced by Dreher (2006) at the Konjunkturforschungsstelle at ETH Zurich, Switzerland from which it takes the name "KOF" (kof.ethz.ch, 2020; Gygli *et al*., 2019). We use the index value for the US. It varies over time. Next, we use a PubMed index which counts the number of published scientific refereed articles about the searched terms (olive oil, healthy diets, etc.). This index only counts the health and medical publications. We use both annual flow and accumulated stock of publications (see pubmed.gov, 2020). We also develop a popularity index reflecting the stock of news articles on Mediterranean diet and health benefits associated with olive oil based on the NewsBank database as in Xiong *et al*. (2014).

In some additional runs (see Review Appendix), we investigate adding yield to capture technical change elements in olive oil production not captured by the unit value. Yield data is incomplete and leads to a decrease in observations. We also look at the impact of regional trade agreements on olive oil trade. Tariffs on olive oil are typically low and do not vary much over time, especially in the context of a single destination. However, deeper market access may have an impact on trade flows via trade facilitation measures. We also look at lead and lag effects of RTAs on olive oil trade flows. These results did not exhibit any robustness once exporter fixed effects are introduced (see Review Appendix table A.1). The limited number of RTAs for the US may also explain the lack of significant results.

Trade flow data are based on US Trade Census. Observations were restricted to the 21 top exporters (Algeria, Argentina, Australia, Brazil, Chile, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Jordan, Lebanon, Morocco, Portugal, Slovenia, Spain, Tunisia, Turkey, and Peru) representing more than 99.8% (for 2019) of imports to the US. Excluded countries from the initial selection are Albania, Canada, China, Japan, Mexico, Montenegro, New Zealand, Palestine, South Africa, and Syria. These countries were excluded because several data series were missing and because of market disruptions, such as in Syria. The panel dataset is available for total exports, imported quantities and prices (import unit values). It extends from 1992 to 2018 consisting of olive oil (HS:1509) and its two major components: virgin oil (HS: 150910) and refined oil (HS:150910). Pomace or residual olive oil (HS:1510) is dropped from the estimation because of many missing observations and its limited use in food consumption. We use physical quantity trade data (variable c_{iUStk} rather than value X_{iUStk}) since we have both physical unit data and import values in US Trade Census. In sum, our panel has 26 years (1992-2018), and 21 countries, with 546 observations. For each olive oil type, there is a considerable number of zeros, which we keep, and some missing unit values which we addressed below.

We have the final empirical specification of trade flows as follows:

$$c_{iUStk} = f\left(realGDP_{US,t}, \frac{UV_{i,US,t,k}}{avgUV_{i,t,k}}, Tot_{exports_{itk}}, fixed\ effect_i, migrant\ stock_{it}, taste\ shifter_{ust}\right) \quad (7)$$

Equation (7) is run in the typical exponential form of the log of continuous variables and fixed effects for the PPML estimation. For the Heckman and truncated OLS specifications, a double log specification of (7) is run. For the Heckman specification, the inverse Mill's Ratio coming from the covariance between selection and level equations is also included as an explanatory variable. We specify the selection equation as follows:

$$L_{iUStk} = f\left(realGDP_{US,t}, \frac{UV_{,i,US,t,k}}{avgUV_{i,t,k}}, Tot_{exports_{itk}}, fixed\ effect_i, migrant\ stock_{it}, taste\ shifter_{ust}, pop_{i,t}, GDP_{i,t}, Cons_{US,t}, Exprev_{i,t}, EU_{i,t}\right) \quad (8)$$

where, L_{iUStk} is the trade latent variable. It takes the following values:

$$\begin{cases} L_{iUStk} = 1 \text{ when } c_{iUStk} > 0 \\ L_{iUStk} = 0 \text{ when } c_{iUStk} = 0 \end{cases}.$$

Variable $pop_{i,t}$ is the exporter's population, $GDP_{i,t}$ is the exporter's GDP, $Exprev_{i,t}$ is the exporter's total olive oil export revenues, and $EU_{i,t}$ is a dummy that indicates whether the exporter is an EU member, all expressed at a time period t. We also included the US consumption of olive oil at a time t, $Cons_{US,t}$, to capture the growth of the market over time. The part-one Probit (or the selection equation) has the same variables as the main Heckman (part-two) equation, with additional variables explaining the decision to export or not and which are excluded from the trade level equation for proper identification. Appendix Table 1 provides a list of the variables, with their definition, units and sources and descriptive statistics.

Dealing with missing observations

For several observations, the import unit values $UV_{i,US,t,k}$ (or in a few cases $avgUV_{i,t,k}$ values were missing which would have resulted in omitting these observations from regressions. This is the case for instance for the zero-trade flow observations which do not have an observed unit value to the US market. We use two instruments to replace missing values of $UV_{i,US,t,k}$, which represent plausible expectations of potential exporters in country i. First, we use the average import unit value of the two geographically closest countries in the sample that are exporting to the US for that year. Distance data from CEPII allow us to compare country pairs distance-wise. For example, Cyprus has the following countries from the sample ordered by increasing distance: Lebanon, Israel, Jordan, Egypt, Turkey, and Greece. We compute its missing unit values by averaging the unit values of Lebanon and Israel, assuming they exist. Second, we assume that the missing UV to the US is expected to be equal to the average unit value for that country and year ($UV_{i,US,t} = avgUV_{i,t}$), which means the "expected" import unit value of i's olive oil for the US equals the average unit value for its worldwide shipments for that year. The choice of instrument has virtually no impact on the results.

Table 2 - Comparative Gravity estimations PPML-PROBIT & HECKMAN.

HS code	*HS 1509*			*HS 150910*			*HS 150990*		
Variables	*PPML*	*PROBIT*	*HECKMAN*	*PPML*	*PROBIT*	*HECKMAN*	*PPML*	*PROBIT*	*HECKMAN*
ln_gdp_USA	0.828*** (0.004)	-1.273 (0.709)	1.093*** (0.007)	2.350*** (0.000)	0.231 (0.949)	2.299*** (0.000)	0.931** (0.023)	-0.029 (0.992)	0.397 (0.710)
ln_IUV	-1.052*** (0.000)	-0.037 (0.841)	-1.337*** (0.000)	-1.295*** (0.000)	-0.158 (0.546)	-1.224*** (0.000)	0.516* (0.052)	0.039 (0.825)	-0.924*** (0.000)
ln_Exporter's total_Exports	0.826*** (0.000)	-0.512 (0.104)	0.824*** (0.000)	0.722*** (0.000)	0.014 (0.963)	0.682*** (0.000)	0.379** (0.042)	0.237 (0.238)	0.414*** (0.000)
ln_Stock_mig	1.145*** (0.000)	0.761*** (0.000)	1.029*** (0.000)	0.973*** (0.000)	0.685*** (0.000)	0.732*** (0.008)	1.341*** (0.000)	0.325*** (0.003)	1.764*** (0.001)
ln_ KOFCuGIdf	0.382 (0.304)	-2.492 (0.269)	-0.113 (0.880)	-0.308 (0.221)	0.195 (0.926)	-1.116 (0.227)	-1.560*** (0.003)	-0.51 (0.753)	0.291 (0.883)
ln_pop_ Exporter		-0.92*** (0.002)			-0.97*** (0.004)			-0.631** (0.012)	
ln_gdp_ Exporter		0.736** (0.033)			1.090** (0.011)			0.748*** (0.003)	
ln_US_ consumption		1.323 (0.403)			0.545 (0.737)			0.655 (0.629)	
ln_tot_exp_ rev		0.900*** (0.006)			0.261 (0.395)			-0.049 (0.808)	
member_eu_ Exporter		0.020 (0.972)			0.023 (0.966)			0.244 (0.460)	
Exporters' Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mill's ratio			0.767*** (0.004)			1.008*** (0.000)			1.930** (0.022)
_cons	-40.69*** (0.000)	12.907 (0.887)	-45.84*** (0.004)	-80.26*** (0.000)	-45.724 (0.637)	-72.43*** (0.000)	-33.81*** (0.005)	-23.25 (0.768)	-30.92 (0.258)
N	542	534	534	515	512	512	484	456	480
R-sq (pseudo)	0.981	0.610	-	0.984	0.632	-	0.956	0.498	-

*P-values in parenthesis. *p=<0.1; **p<0.05; ***p<0.01. Country specific fixed effects of this regression were deleted from this table for simplicity reasons*

4. Results

Table 2 presents the estimation results for the chosen estimations methods (PPML and Heckman sample selection (with its Probit selection equation)). Truncated OLS was also estimated (see Review Appendix Table A.3). All specifications include exporter fixed effects, which are not reported to save space. Country fixed effects are significant, except for France, Croatia, Jordan, and Portugal. Peru is omitted and in the intercept. Results are available upon request. The three oil categories are run as separate regressions. In separate runs with the disaggregated categories (HS 150910 and 150990) we included cross-price effects which were not significant.

All models explain well the variation of the import level (R^2 for olive oil HS1509 and its subcategories >0.9). The unit value ratio as a price proxy for trade cost and exporter trade resistance has the expected negative sign, except for the refined lower quality oils HS:150990 that has an insignificant positive sign. Similarly, the GDP as proxy for income has a systematically significant and positive sign, which confirms the aggregate income effect for olive oil products in the US. The refined olive oil HS:150990 with its lower quality has an insignificant income coefficient.

Among non-price determinants, the candidate variables were tried with mixed success. First, network effects appear to be very robust in all equations, the stock of migrants from exporting countries living in the US explain much of the variation of olive oil imports over time and across export sources. For the shift of taste parameters, we tried several combinations of the KOF index and PubMed and NewsBank indices, both in stock and flow form. However, we could not find robust results, the estimations were plagued by sign reversals, and loss of significance. In addition, the inclusion of these variables in the specification tends to dilute the significance of the income variable. Hence, we are not confident that we can capture the alleged taste changes with these indices, beyond the cultural influence captured by the migrant network variable. Detailed results are reported in the Review Appendix. Table 2 below illustrates the type of insignificant results which we obtained (here with the KOF index).

A comparative horizontal reading of Table 2 gives a cross quality comparison for oils. The higher quality virgin olive oil (HS:150910) has generally a higher price and income response than its lower quality analogue (HS:150990). Migrants' stock has almost the same effect on both subcategories. Olive oil (HS:1509) that regroups both subcategories, shows effects that are close to the average of the effects on two subcomponents at the HS-6 level.

The Heckman sample selection specification is also shown in Table 2. Its first-stage Probit explains the extensive margin for exporters who decide to export or not. The Probit explains about 60% of the variation of the dependent variable (R^2 of 0.6) in most runs. It shows that migrants' stock, exporters' GDP, exporters' population, and total exports revenue are among significant factors that influence decisions to initiate exports of olive oil to the US. This result also provides some insight on the business-network of migrant to create new trade (the extensive margin) as opposed to their influence on the intensive margin through their expanding cultural influence. Heckman's second stage (trade levels) provides results comparable to PPML and truncated OLS results (see Review Appendix Table A.3). Coefficients' signs and robustness are similar to PPML, with stronger price and income response for the higher quality virgin olive oil HS:150910. Heckman's Mills' ratio significance suggests that sample selection is present.

Table 3 presents RESET tests for the models

Table 3 - RESET test.

HS / Test results	*1509*				*150910*				*150990*			
	OLS	PPML	PROBIT	*HECKMAN*	OLS	PPML	PROBIT	*HECKMAN*	OLS	PPML	PROBIT	*HECKMAN*
RESET test P-Value	0.792	0.0684	0.203	0.652	0.000	0.0017	0.0238	0.0000	0.0000	0.0000	0.0237	0.8333
Chi2/F-value	0.35	3.32	1.62	0.20	8.22	9.81	5.11	18.71	9.71	32.95	5.12	0.04
N	449	542	534	534	413	515	512	512	332	484	456	480
R-sq (pseudo)	0.937	0.981	0.61	-	0.921	0.984	0.63	-	0.874	0.956	0.498	-

Table 4 - HPC test.

HS / Test results	*1509*		*150910*		*150990*	
HPC test	PPML	HECKMAN	PPML	HECKMAN	PPML	HECKMAN
P-Value	0.000	0.133	0.000	0.181	0.000	0.535
T-value	9.280	1.114	14.694	0.913	9.663	-0.087
N	534	534	511	512	477	480
R-sq (pseudo)	0.981	-	0.984	-	0.956	-

shown in Table 2. For the aggregate olive oil (HS:1509), the RESET tests suggest that the Heckman trade volume equation is acceptable. The Reset test for PPML is borderline significant at 10% but not at 5% or less. We read it as inconclusive. For the disaggregated regressions (150910 and 150990), the RESET tests indicate evidence of misspecification for the chosen specifications. The Heckman trade volume equation fails the reset test for 150910 but passes the test for 150990. Table 4 presents the HPC tests in a comparison between PPML and Heckman sample selection models to discriminate the best model (one-part versus two-part models) for our data. The HPC test uses predicted trade levels but based on a logarithmic estimation for the Heckman and in trade levels for PPML. The Heckman estimated values are then reconverted in levels for the test, following Santos Silva *et al*. (2015). The test clearly rejects PPML, while not rejecting Heckman for both aggregate and disaggregated trade flows.

We conclude that both RESET and HPC tests suggest the Heckman sample-selection model provides the best fit for our data to address the US import demand determinants for olive oil, compared to PPML. The Inverse Mills Ratio is also significant which suggests that the error terms of the selection equation and the trade equation are correlated. The extensive margin contributes to explaining why exporting countries enter or not the US market for olive oil. The selection equation shows the positive role of migrant networks on the extensive margin of trade.

Beyond the specifications presented in Table 2, multiple variations in specifications were tried. We added yield, to capture technical change. However, several countries had missing yield data, leading to a decrease in observations. Results were not robust with sign reversal and various level of significance. Regional trade agreements (RTA) between the US and its partners were also introduced, including lag and lead effects to attempt to capture potential effects of deeper trade integration. (See Review Appendix table A.1 for an example of RTA specification). Results again were not robust. Both were removed from our preferred specification because exporters' fixed effects capture much of these two variables, except their time variation.

In addition, bilateral distance which, often used to proxy bilateral trade cost, was tried and found not to be robust. It exhibited sign reversal (significant positive sign), the inverse of what the theory suggests. Three elements contribute to this non result. The lack of variation in destinations combined with the geography of olive production is the first and second ones. Most of olive oil exporters are located in the Mediterranean basin (say, as opposed to Mexico and Canada for other commodities) and quality differs from an exporter to another with new-world exporters (Chile, Argentina) just emerging relative to further-distant established EU exporters. Last, our unit cost ratio variable incorporates the cost of shipping the various olive oils. It is a solid proxy for several trade costs including the cost of overcoming distance.

Finally, for both subcategories of olive oil (virgin and refined), we have thought of testing cross-price effects in the specifications. It appeared that cross-prices were not significant with no effect on the explanatory variables nor the R^2.

5. Discussion

This paper investigated the determinants of US import demand and export supply of olive oil in a partial equilibrium framework accounting for both demand and supply determinants. We used an augmented gravity equation equilibrium framework applied to the single destination US market. the most novel and interesting results pertain to immigrant network effects. On the demand side, we find that migrant networks exhibit a systematic positive influence on demand via a cultural element in the intensive margin of trade reflecting new preferences for olive oil. These migrant communities and networks propagate new culinary habits and food consumption, in this case, the Mediterranean diet and olive oil. Related to the supply side, we found strong network effects at the extensive margin, created by immigrants from exporting countries. These networks facilitate new trade flows, through their influence in business networks lowering the cost of entry into the US market for new exporters.

Related to conventional determinants of demand, we found that income and relative prices are important determinants of olive oil demand with high elasticities in the case of virgin olive oil. Beyond this strong result related to migrant networks, and despite using several alternative proxies to measure the influence of information and cultural influences on US olive oil demand, we could not find any additional robust association, somewhat to our surprise. This result is in contrast to Xiong *et al*. We use a much finer disaggregation of olive oil by origin relative to Xiong *et al*. who abstracted from the influence of migrant network in their context. The strong aggregation in Xiong *et al*. smooths out much of the variability we have in the bilateral flows and allows for identifying an aggregate trend, too difficult to identify in our disaggregated bilateral flows.

On the supply side, exporters' specific fixed effects were used to absorb the cross-sectional variation among olive oil exporters to the US market. The variability of export supply over time and geography was captured by the time-varying value of exports to all destinations for each exporter. In addition, the relative trade costs of destination markets were captured by the ratio of the trade unit value to the US relative to those of other destinations, and this for each exporter.

In the Heckman selection model, besides the network effect, other variables influence the extensive margin, including the exporter's GDP, population, and total exports revenues, as suggested by the Probit results. From an empirical point of view, the Heckman sample selection specification was the best model to fit the data and did not exhibit evidence of misspecification as suggested by the RESET test. The HPC test suggests that the Heckman sample selection with its explicit extensive margin fits the data better than the PPML approach does. PPML provides a legitimate way to incorporate zero but lacks the extensive margin component.

In future investigations and using shorter time series, one could further disaggregate olive oil at the HS-8 or HS-10 levels. In addition, a decomposition of bulk/non-bulk packaging, and a consideration of organic and labelled subcategories of olive oil could help provide deeper insights on the quality upgrade and market segmentation which took place over time in the US market.

6. Conclusions

The main conclusions are first that migrant networks from exporting countries matter a lot to rationalize the growth of the US olive oil market driving culinary changes in consumption and business network facilitating the entry of exporters. Secondly, price and income responses are large, especially for virgin olive oil, linking US economic prosperity and the growth of these markets while maintaining a competitive pricing environment.

These findings offer valuable insights for US olive oil traders, growers, trade policymakers, and stakeholders, enabling them to understand the reasons behind the growing interest in and spending on olive oil by US consumers within the context of a dynamic global olive oil market. This understanding empowers established and new stakeholders in the US olive oil market to monitor emerging trends and devise appropriate strategies, including pricing and market segmentation in virgin olive oil to optimize their respective positions and overall well-being.

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Appendix

Summary Table of Regression Variables

Variable	*definition*	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*	*Unit*	*Source*
FL_1509	Bilateral trade volume HS 1509	567	1.06E+07	3.00E+07	0	1.60E+08	Kg	US Trade Census, 2020
FL_150910	Bilateral trade volume HS 150910	567	6487873	1.86E+07	0	1.10E+08	Kg	US Trade Census, 2020
FL_150990	Bilateral trade volume HS 150990	567	4078652	1.27E+07	0	8.25E+07	Kg	US Trade Census, 2020
GDP_USA	Aggregate US income	567	1.38E+13	2.43E+12	9.38E+12	1.79E+13	USD	CEPII database, 2020
IUV _1509	Relative bilateral unit value HS 1509	554	1.255093	2.937924	0.021978	68.55963	Ratio, index	US Trade Census, 2020
IUV _150910	Relative bilateral unit value HS 150910	557	1.714746	10.25325	0.2003365	217.1838	Ratio, index	US Trade Census, 2020
IUV _150990	Relative bilateral unit value HS 150990	550	1.397808	3.715903	0.1140869	78.16504	Ratio, index	US Trade Census, 2020
STOCK_MIG	Stock of migrants from country *i* in the US	567	119556.6	112751.2	8	505831	Person	OIS, 2021
KOFCUGIDF	KOF index of globalization	567	81.56524	7.051316	71.24317	91.72095	index	kof.ethz.ch, 2020; Gygli *et al.*, 2019
POP_EXPORTER	Exporter's population	567	34.22425	41.31275	0.6106	209.4693	Person	CEPII database, 2020
GDP_EXPORTER	Exporter's aggregate income	558	4.85E+11	6.40E+11	1.10E+10	2.57E+12	USD	CEPII database, 2020
US_CONSUMPTION	US olive oil consumption	567	236.4815	75.76036	104	364	1000 tons	USDA-FAS, PS&D, 2020
TOT_EXPORTS~1509	Total exports 1509 by country *i*	562	2.09E+08	5.43E+08	0	4.16E+09	Tonnes	FAOStat, 2021
TOT_EXPORTS~150910	Total exports 150910 by country *i*	521	1.61E+08	4.05E+08	65	3.15E+09	Tonnes	FAOStat, 2021
TOT_EXPORTS~150990	Total exports 150990 by country *i*	495	4.05E+07	1.06E+08	0	8.84E+08	Tonnes	FAOStat, 2021
MEMBER_EU_O	Membership in the EU	567	0.3015873	0.4593523	0	1	Dummy	CEPII database, 2020