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Food safety and food imports in Europe: the risk of aflatoxins in pistachios

RESEARCH ARTICLE

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Abstract

The United States has surpassed Iran as the largest pistachio exporter to the European Union. Both lower prices and a less frequency of aflatoxin contamination have contributed to the success of the US pistachio industry. Using EU monthly imports and food safety alerts data, we estimate EU demand for US and Iranian pistachios. We find that EU demand for US pistachios is price-inelastic but the demand for Iranian pistachios is price-elastic. We also find that the income effect is positive for US nuts but negative for Iranian nuts. Most importantly, we find that EU imports of US pistachios decrease with aflatoxin alerts traced back to the US but increase with contamination incidents originated from Iran.

Keywords: pistachio, tree nut, aflatoxin, food safety, trade
JEL code: Q17, Q18

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1. Introduction

The world market for pistachios

The average world consumption of pistachios is 475,000 metric tons per year over the period 2009-2012 (Pistachio PSD USDA-FAS, 2016). The United States and Iran are the top two producers in the world. Specifically, the United States supplies 180,000 tons (or 38%) annually and Iran produces 160,000 tons (or 34%) per year.[1] Other major producing nations are Turkey and Syria, jointly supplying 130,000 tons (or 28%).

Because of the high concentration of production, international trade is important to the pistachio market. Nearly 200,000 to 300,000 tons of pistachios are traded across national borders each year (excluding intra-EU trade). The United States and Iran are the dominant exporting countries, accounting for 50 and 45% of world exports, respectively. Among various destination markets, the EU is the world's largest importing region at 30% of the world's total imports.

Changes in the EU market

The United States has surpassed Iran as the largest pistachio supplier to the EU. As shown in Figure 1, US monthly pistachio exports to the EU increased from 1000 tons in 1999 to nearly 3,500 tons in 2012. During the same period, Iranian exports to the EU declined from 4,000 tons to less than 1,500 tons per month.

What explains the rise of US and the decline of Iran in the European pistachio market? The change in relative prices is one reason. As shown in Figure 2, US pistachios have become more competitive than Iranian pistachios in recent years. The comparative advantage of US pistachios is primarily driven by higher yields in California as a result of improved management practices. In particular, Geisseler and Horwath (2016) report that Californian pistachio yield has steadily risen to 3,541.9 kg/ha as of 2012, while Iranian pistachio yield remains at 1,814.7 kg/ha according to FAOSTAT (2016).

[1] The production quantities are averaged over four consecutive years, 2009-2012, because pistachio trees feature alternate bearing.

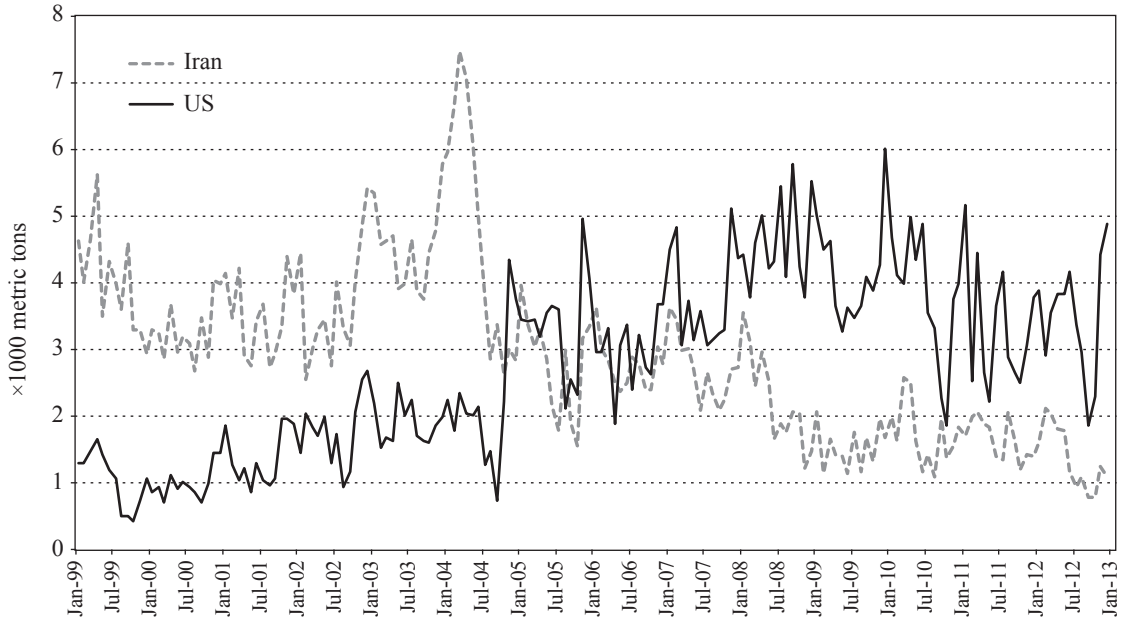

Figure 1. EU monthly imports of pistachio from Iran and United States, 1000 metric tons (adapted from EUROSTAT, http://ec.europa.eu/eurostat).

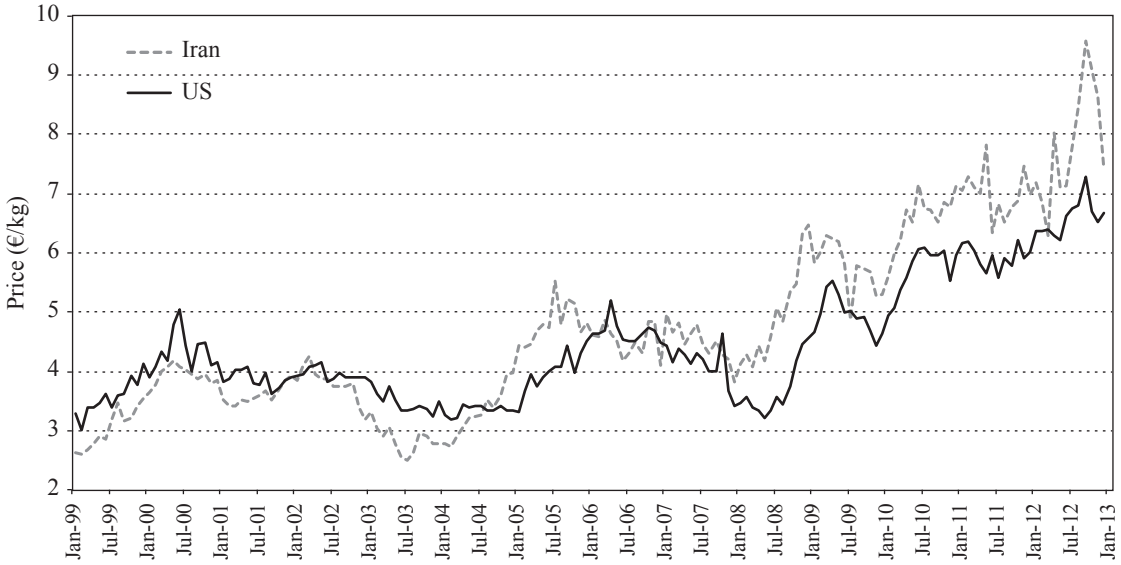

Figure 2. EU monthly import prices of Iranian and US pistachios in €/kg. Import prices are the cost, insurance and freight prices measured as the unit-values of imported pistachios at EU customs (adapted from EUROSTAT, http://ec.europa.eu/eurostat).

Nevertheless, the US price advantage is no more than €1 per kilogram based on Figure 2.[2] Therefore, non-price factors such as food safety issues presumably play an important role in driving the consumption trends in Europe.

Aflatoxin control in the European Union and the United States

Aflatoxins are naturally occurring substances produced by certain fungi growing on nut products, maize, and other agricultural commodities. The fungi are more likely to develop under hot and humid conditions. Acute intoxication through aflatoxin-contaminated food can lead to liver damages or developmental delays, and feedstuff spoiled with aflatoxin causes weight loss in animals.

Aflatoxin control in pistachios is an important food safety measure in the EU. In 1997, the European Commission (EC) temporally suspended imports of Iranian pistachios because of severe aflatoxin contaminations (EC, 1997a). Although the ban was repealed later in the year, restrictive measures were imposed on pistachio imports from Iran, including mandatory sampling and testing procedures at customs (EC, 1997b). In April 2002, the EC set the union-wide maximum residue limits (MRLs) for the aflatoxin content in food and feed (EC, 2001, 2002). The EU MRL is 10 µg/kg for pistachios for direct human consumption and 15 µg/kg for pistachios subject to further processing. In December 2006, the EC modified some MRLs but the MRLs for aflatoxins in nut products remained (EC, 2006). In November 2009, due to the high risk of aflatoxin contamination, the EC imposed more rules governing the imports of specified products from specified countries, including pistachio and derived products from Iran and Turkey (EC, 2009).

Figure 3 shows that aflatoxin contamination in pistachios is more severe in Iran than in the US From 1999 to 2012, there were a total of 98 EC alerts concerning aflatoxin-spoiled pistachios traced back to Iran. In comparison, only 21 alerts involved US pistachios during the same period. Therefore, aflatoxin control measures in the EU can be a key factor that changes the landscape of international pistachio markets.

[2] In Supplementary Table S1 we show that the price of US pistachios was higher than that of Iranian pistachios over the period 1999-2007. However, the price of US pistachios was lower than that of Iranian pistachios by 1 euro/kg over the period 2008-2012. Both test results are statistically significant.

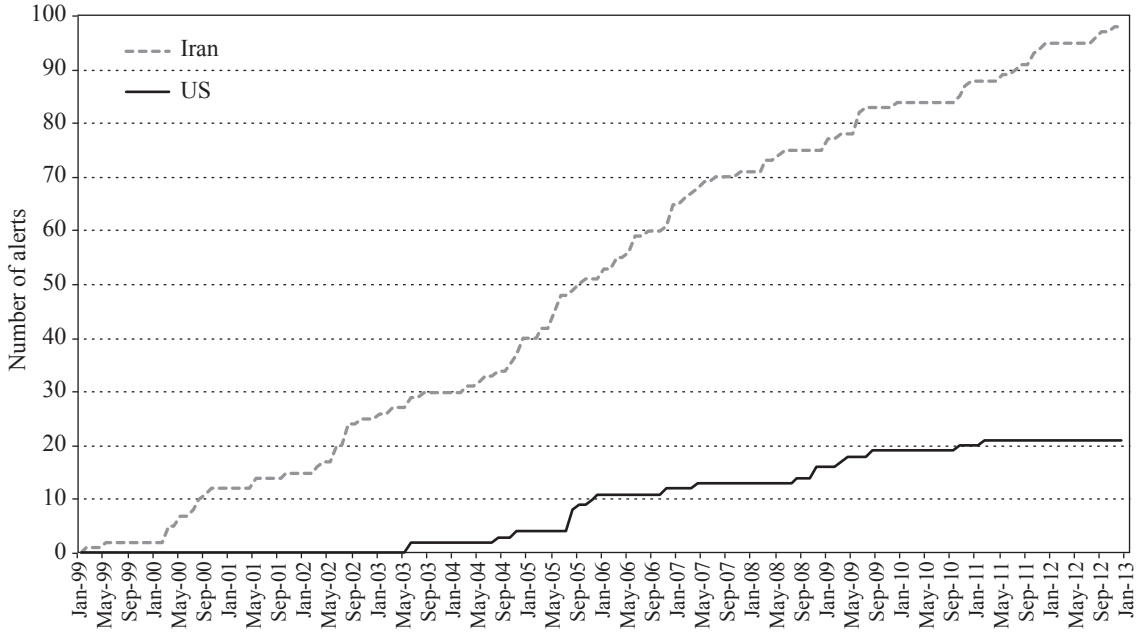

Figure 3. EU accumulative alerts of aflatoxin-contaminated pistachios imported from Iran and United States (adapted from RASFF, 2016).

Aflatoxin policy in the United States has also been enhanced over the past decade. The US had been using 20 μg/kg as the MRL for aflatoxin content in all foods (except for milk) since 1969 (FAO, 2004). In August 2005, a federal marketing order (FMO) initiated by the US pistachio industry took effect.[3] The FMO requires mandatory testing for aflatoxin content for all pistachios marketed in the United States, Canada, and Mexico.[4] The effective MRL for aflatoxins in the United States is 15 μg/kg, which is as stringent as the EU standard. Gray *et al.* (2005) project that the benefit of the FMO, through enhancing consumer demand, should outweigh the cost of the program. Because the aflatoxin standards implied by the FMO are less stringent than the EU standards, we stipulate that the FMO has negligible impacts on nut importers in Europe.

Summary of key findings

We contribute to the understanding of food import and food safety by offering a case study of the EU pistachio market. The market is unique in that the supply is dominated by two countries: United States, a developed nation, and Iran, a developing nation. Therefore, our case study is an ideal experiment to investigate the distributional effects of food safety policies on agricultural exporters from countries of different development stages.

Using EU monthly import and food safety alert data from 1999 to 2012, we estimate EU demand for US and Iranian pistachios. We find that EU demand for US pistachios is price-inelastic but the demand for Iranian pistachios is price-elastic. We also find that the income effect is positive for US nuts but negative for Iranian nuts. Most importantly, we find that EU imports of US pistachios decrease with aflatoxin alerts traced back to US pistachios but increase with contamination incidents originated from Iran. In particular, we estimate that ten more food safety alerts involving US pistachios would reduce EU monthly imports of US nuts by 167 tons, while ten more alerts concerning Iranian pistachios would raise EU imports of US nuts by 200 tons a month.

[3] http://tinyurl.com/z9nmhsz.

[4] Pistachio production in North America is concentrated in San Joaquin Valley and surrounding areas in California. Over the past decade, the region has invested heavily in tree nuts such as almond, pistachios, and walnut, as well as fruits such as grapes and cherries. Traditionally, the agricultural sector within the region was dominated by dairy farms and cattle ranches.

The rest of the article is organized as follows. In Section 2 we introduce the empirical specification to characterize the EU imports of pistachios. We present the data and their sources in Section 3 and discuss the econometric results in Section 4. In Section 5 we offer concluding remarks and suggest directions for future research.

2. EU demand for pistachios

Literature on food safety and food import

Previous research on the impact of food safety policy, or non-tariff measures in general, often uses the gravity equation approach.[5] Otsuki *et al.* (2001) projected that the harmonization of aflatoxin policies within the EU would reduce Africa's exports of cereals, dried fruits and nuts by 64%. Disdier *et al.* (2008) find that the sanitary and phyto-sanitary measures and technical barriers to trade significantly constrain developing countries' agricultural exports to the OECD markets. Munasib and Roy (2011) report that maize exporters from poor countries are negatively affected by aflatoxin control in the developed world. Xiong and Beghin (2012) find that EU aflatoxin policies have negligible impacts on groundnut exports from Africa to Europe. Winchester *et al.* (2012) report that cross-country differences in pesticide regulations reduces EU trade in plant products with major partners, with the magnitude of the trade distortion varying substantially across sectors.

Despite its empirical success, the gravity equation approach does not attend to price effects, which are important to the pistachio market because other tree nuts can be close substitutes or complements. To characterize substitution patterns across a variety of tree nuts, we use a partial demand system to model EU imports of pistachios. In a related study, Zheng *et al.* (2012) empirically estimate the export of US pistachios, with food safety attributes measured by incidents from the Google news timeline.

The econometric specification

The EU pistachio imports respond to prices of pistachios and other types of tree nuts, the EU income level, and the EU-wide food safety alerts. Following LaFrance (1990), we specify EU import demand functions for pistachios as:

$$q_t^{US} = \alpha_0 + \alpha_1 I_t + \alpha_2[p_t^{US}(1+tar_t^{US})] + \alpha_3[p_t^{Iran}(1+tar_t^{Iran})] + \alpha_4 p_t^a + \alpha_5 p_t^h + \alpha_6 fa_t^{Iran} - \alpha_7 fa_t^{US} + \mu_t \quad (1)$$

$$q_t^{Iran} = \beta_0 + \beta_1 I_t + \beta_2[p_t^{Iran}(1+tar_t^{Iran})] + \beta_3[p_t^{US}(1+tar_t^{US})] + \beta_4 p_t^a + \beta_5 p_t^h + \beta_6 fa_t^{Iran} - \beta_7 fa_t^{US} + \nu_t \quad (2)$$

where q_t^{US} is the quantity of pistachios EU imports from the US, I_t is EU quarterly GDP smoothed over months, p_t^{US} and p_t^{Iran} are the EU import prices of US and Iranian pistachios, tar_t^{US} and tar_t^{Iran} are the *ad valorem* tariff rates EU imposes on pistachios of two origins, and p_t^a and p_t^h are EU import prices of US almonds and Turkish hazelnuts, respectively.[6] By including the prices of the two alternative tree nuts, we relate EU imports of pistachios to its imports of other types of nut products. Because the US and Turkey are the dominant suppliers of almonds and hazelnuts, the two price series represent world prices.[7]

In Equation 1, the variable fa_t^{Iran} denotes the frequency of aflatoxin alerts involving pistachios imported from Iran. Specifically:

[5] See Anderson and Van Wincoop (2003) for a derivation of the gravity equation. Alternatively, the price-wedge method is used to analyze non-tariff barriers. For example, Nimenya *et al.* (2012) assess the impact of EU non-tariff measures on imports of horticultural and fish products from Africa. Bureau and Beghin (2001) provide a review of different methods in the analysis of non-tariff measures.

[6] Note that we omit EU domestic price of pistachios because EU production accounts for 2% of world pistachio production (Pistachio PSD USDA-FAS, 2016).

[7] We omit the prices of other tree nuts (e.g. pecans, walnuts, Brazil nuts) because EU import of these nut products is small in quantity. We also omit EU import duties on US almonds and Turkish hazelnuts because both duty rates remain constant over the past decade.

$$fa_t^{Iran} = \frac{\sum_{m=1}^{t-1} alerts_m^{Iran}}{\sum_{m=1}^{t-1} q_m^{Iran}} \quad (3)$$

Intuitively, the variable uses historical information on food safety and import to measure the extent to which a ton of Iranian pistachios is at risk of aflatoxin contamination. This novel measurement improves upon the simple count of Rapid Alert System for Food and Feed (RASFF) alerts in Jaud *et al*. (2013) by addressing the endogeneity problem of the count variable.[8] That is, with food safety risk held constant, a product traded in higher volumes triggers more alerts because the base for sampling and testing is larger. It is also worth noting that we implicitly assume that the consignments affected by alerts are comparable in volumes. Ideally, the number of alerts should be further translated into the quantity of contaminated pistachios. Unfortunately, the RASFF database does not provide information on the volumes of the at-risk consignments. Similarly, we measure the frequency of aflatoxin contamination in US pistachios by the variable:

$$fa_t^{US} = \frac{\sum_{n=1}^{t-1} alerts_n^{US}}{\sum_{n=1}^{t-1} q_n^{US}} \quad (4)$$

We focus on aflatoxin incidents because they are the primary food safety concern in pistachio nuts.

The empirical specification Equation (1)-(2) has two major advantages. First, the measurement of the severity of food safety incidents is normalized by the size of import. This novel approach allows us to disentangle the food safety effect from the market size effect. Second, the specification explicitly controls for the substitution patterns between pistachios and alternative tree nuts. Therefore, the forthcoming results are informative to stakeholders in the business of tree nuts in general.

3. The data

The custom data

Using the EUROSTAT database (http://ec.europa.eu/eurostat), we retrieve monthly imports of pistachios, from Iran and the United States, respectively, for the 27 EU member states from January 1999 to December 2012.[9] We start the period of examination from January 1999 for two reasons. First, the EU banned Iranian pistachios in 1997 and applied highly restrictive measures against Iranian nuts in 1998. Second, the import data are available in both value (euro) and quantity (kilogram) since January 1999.

We compute the import prices of Iranian and US pistachios by taking the ratio of the import values over the import quantities. The unit-value measurement of prices is likely subject to measurement errors. Specifically, any potential error in the quantity series would introduce a negative correlation between the price and quantity measurements, resulting in biased estimates. After reviewing the data, however, we stipulate that the magnitude of the potential bias should be limited for two reasons. First, random errors due to rounding are unlikely because the value and quantity series are recorded down to the last digit of euro and kilogram. Second, the data aggregation from the port level to the EU level mitigates idiosyncratic measurement errors at individual customs. In a similar way, we compute EU monthly import prices of US almonds and Turkish hazelnuts.

[8] Similar to Jaud *et al.* (2013) and Piggott and Marsh (2004) use the count of articles published in major newspapers to measure the safety of meat products in the United States.

[9] Since January 2012 the Harmonized System further classifies pistachios into in-shell pistachios (HS 080251) and shelled pistachios (HS 080252). Over 90% of EU imports of pistachios are in-shell nuts. We aggregate the two categories into in-shell equivalence.

The rapid alert system for food and feed data

The RASFF of the EU informs member states of the detected risks related to food and feed products.[10] There are two types of RASFF alerts: market notifications and border rejections. A market notification is triggered when the identified risk requires rapid actions from all member states (e.g. withdrawal of the product). A border rejection denies the entry of the consignment for safety, labeling, or other specification issues. In the empirical analysis we focus on market notifications because they are directly relevant to the entire EU market.

We collect all RASFF market notifications concerning aflatoxin-contaminated pistachios or derived products, imported from Iran and the US For example, on January 6th 2011, the United Kingdom identified that some unsalted pistachio nuts imported from the United States contained aflatoxin B_1 above the EU MRL. Consequently, the RASFF issued a market notification requiring all member states to withdraw the products from the marketplace.

Admittedly, the RASFF market notification data do not fully reflect the severity of food, safety problems for two reasons. First, RASFF does not disclose the volume or the value of an affected shipment. Second, RASFF does not provide information on the extent to which the EU standards are violated.[11] Nevertheless, RASFF remains a systemic and up-to-date databank for food safety issues.

The tariff and exchange rate data

We use the EU effectively applied tariff rates from the TRAINS database of the World Bank (http://tinyurl.com/zsfnckj). The *ad valorem* rates faced by Iran and the US are available for 2008 and 2009. We complement the TRAINS tariff data with current duty rates listed in the EC TARIC database.[12] The EU third-country rate for pistachios is 1.6%. We extract monthly real exchange rates from the Economic Research Service of the US Department of Agriculture.[13] We express exchange rates in terms of per euro. In Supplementary Table S2, we present summary statistics of all variables used in the estimation.

4. Results and discussions

Model validation checks

■ *Unit root tests*

Since we use monthly data spanning from 1999 to 2012, we first check the stationarity of EU import quantities of pistachios. The Dickey-Fuller unit root test results suggest that neither the import quantity of Iranian pistachios nor that of US nuts contains unit roots.[14] Therefore, the system Equation (1)-(2) can be estimated in its original form as opposed to in its differenced specification.

■ *Endogeneity of import prices*

The endogeneity of pistachio prices is another caveat in the empirical estimation. In recent years, the EU imports from Iran accounts for nearly 15% of all Iranian pistachio exports and EU imports from the US amount to 27% of all US pistachio exports (Pistachio PSD USDA-FAS, 2016). Therefore, any unobservable determinants of EU import demand are likely to affect the world prices of pistachios as well. To check the

[10] The RASFF data portal can be accessed at http://tinyurl.com/zaer5l8.
[11] As an illustration, a parcel of pistachios tested 16 µg/kg enters into the RASFF system in the same way as a parcel of pistachios tested 50 µg/kg.
[12] The exchange rate data is available from http://tinyurl.com/jjqgzod.
[13] The data is available at http://tinyurl.com/jaey6rq. Because the real exchange rate for the Iranian rial is unavailable on a monthly basis, we use the annual estimates as an approximation.
[14] The associated test results are available in Supplementary Table S3.

exogeneity of EU import prices of pistachios, we conduct the Hausman-Durbin-Wu tests with monthly real exchange rates (i.e. dollar per euro and rial per euro) as the instrumental variables.[15]

The Hausman-Durbin-Wu test results suggest that EU import price of US pistachios can be taken as exogenous but EU import price of Iranian pistachios is endogenously determined. To address the endogenous price of Iranian pistachios, we combine the system Equation (1)-(2) with a third equation that explains EU import price of Iranian pistachios. Specifically, we use all exogenous variables including the two exchange rates as the potential determinants of the import price of Iranian nuts.

■ *The properties of demand*

To ensure that our empirical specification satisfies Marshallian symmetry, we impose the parameter restriction $\alpha_3=\beta_3$. Note that we use Marshallian symmetry to approximate Hicksian symmetry because the expenditure on pistachios accounts for a tiny share in the overall budget (LaFrance, 1990). To retain the homogeneity of degree zero in all nominal terms, we deflate all monetary measurements by EU monthly Consumer Price Indices (CPI).[16]

The benchmark results

We use the three-stage least square procedure to estimate the system Equation (1)-(2) in which the price of Iranian pistachios is endogenously determined. Table 1 displays the estimation results.

As shown in Table 1, the EU's demand for US pistachios decreases with the price of US pistachios and increases with the price of Iranian pistachios. The substitutability between US and Iranian pistachios is also reported by Zheng *et al.* (2012). We also find that the demand for U.S pistachios rises with the income level in Europe. Furthermore, we find that US pistachios are complements to US almonds but substitutes for Turkish hazelnuts. We later discuss the relations among various tree nuts in more detail. Most importantly,

[15] The results of the Hausman-Durbin-Wu tests are available in Supplementary Table S4.
[16] For example, if all prices double, the CPI doubles as well. Therefore, all real prices are unchanged, so is the demand.

Table 1. Regression results for EU imports of pistachios, 1999-2012.[1,2]

	Import quantity of US pistachio	**Import quantity of Iranian pistachio**	**Import price of Iranian pistachio**
Import price of US pistachio	-34.08*** (11.70)	32.40*** (10.17)	0.491*** (0.051)
Import price of Iranian pistachio	32.40*** (10.17)	-110.6*** (11.89)	n.a.
Real exchange rate (dollar/euro)	n.a.	n.a.	-0.016*** (0.003)
Real exchange rate (1000 rial/euro)	n.a.	n.a.	-0.002*** (0.000)
EU income	0.535*** (0.075)	-0.189*** (0.062)	-0.000 (0.000)
Import price of US almond	-45.83*** (11.23)	49.20*** (9.778)	-0.050 (0.070)
Import price of Turkish hazelnut	36.37*** (10.48)	-29.93*** (9.632)	0.288*** (0.058)
Frequency of aflatoxin incidents, traced to US	-7.768*** (2.674)	-3.086 (2.360)	0.053*** (0.0168)
Frequency of aflatoxin incidents, traced to Iran	9.308*** (2.765)	2.320 (2.408)	-0.056*** (0.018)
Constant	-13.07*** (1.988)	11.27*** (1.628)	0.083*** (0.013)
R^2	0.61	0.71	0.81

[1] The Hausman-Durbin-Wu test suggests that EU import price of Iranian pistachios is endogenous. Therefore, the price variable is instrumented by monthly exchange rates of dollar and rial relative to euros.
[2] Standard errors are in parentheses; *** denotes significance levels of 1%; n.a. = not available.

we find that EU demand for US pistachios is significantly affected by food safety hazards. In particular, aflatoxin contamination incidents traced back to US pistachios significantly reduce EU imports of US nuts, and similar incidents originated from Iran enhance EU demand for US pistachios. In an earlier study of US pistachio export, Zheng *et al.* (2012) also test the food safety effects but their empirical analysis does not confirm the trade-impeding effect of food safety incidents.

Turning to EU imports of Iranian pistachios in Table 1, we find that the EU demand for Iranian nuts decreases with the own price and increases with the price of the US pistachios. We also find that EU consumption of Iranian pistachios declines as the income level rises. In addition, we find that Iranian pistachios substitute with US almonds but complement Turkish hazelnuts. We discuss these patterns in detail after we derive the associated cross-price elasticities. In terms of food safety effects, the estimates suggest that the EU imports of Iranian pistachios do not respond to aflatoxin incidents in a statistically significant way.

Finally, we attend to the price equation in Table 1. We find that the price of Iranian pistachios is positively correlated with the price of US pistachios. As expected, a weaker rial makes the Iranian nuts more competitive. However, we also find that a weaker dollar improves the competitiveness of the Iranian nuts. This counter-intuitive result might have to with the role of US dollar as international currency.[17] Furthermore, we find that the price of Iranian pistachios moves together with the price of Turkish hazelnuts. Most importantly, we show that Iranian pistachios are sold as discounted prices when the nuts suffer from food safety incidents, and gain price premiums when the US nuts are exposed to aflatoxin risks. This result is consistent with the notion that the attribute of food safety is partially reflected in market prices.[18]

Using the estimated coefficients in Table 1, we derive the associated elasticities and report them in Table 2. We find that EU demand for US pistachios is price-inelastic, with the own price elasticity at 0.5. In contrast, EU demand for Iranian pistachios is sensitive to price variations, with the own price elasticity at 4. This high responsiveness can be explained by two plausible factors. First, EU imports of Iranian pistachios declined to record low in 2011-2012 (Figure 1). Therefore, the elasticity evaluated at the low trade volume is high by definition. Second, the sensitivity to price changes of the Iranian nuts partially reflects European consumers' long-held risk perception before the launch of RASFF in 1979.[19]

In terms of the income effects, we find from Table 2 that the EU's income elasticity for US pistachios is over 4, much higher than the income elasticity for most agricultural commodities (which often ranges between zero

[17] One possible explanation is that a weak US dollar indicates a sluggish world economy, which suppresses prices of commodities.
[18] See Caswell and Mojduszka (1996) for a discussion of the credence nature of food safety attributes.
[19] For example, Mojtahedi *et al*. (1979) documented the agronomic conditions that result in the development of aflatoxins in Iranian pistachios.

Table 2. Estimated elasticities for EU imports of pistachios, 1999-2012.[1,2]

	Import quantity of US pistachio	**Import quantity of Iranian pistachio**
Import price of US pistachio	-0.546*** (0.188)	1.060*** (0.333)
Import price of Iranian pistachio	0.597*** (0.187)	-4.159*** (0.447)
EU income	4.378*** (0.610)	-3.156*** (1.028)
Import price of US almond	-0.406*** (0.099)	0.889*** (0.177)
Import price of Turkish hazelnut	0.498*** (0.144)	-0.837*** (0.269)
Frequency of aflatoxin incidents, traced to US	-0.129*** (0.045)	-0.105 (0.080)
Frequency of aflatoxin incidents, traced to Iran	0.588*** (0.175)	0.299 (0.310)

[1] To reflect recent market trends, all elasticities are evaluated at the sample means in the period of marketing year 2010/2011 and 2011/2012.
[2] Standard errors are in parentheses; *** denotes significance levels of 1%.

and one). This finding suggests that US pistachio is perceived as a luxury product in Europe. Nevertheless, the extremely large income effect might also be entangled with European consumers' rising awareness of the health benefits of tree nuts.[20] In contrast, the income effect for Iranian pistachios is negative, indicating that European consumers shift away from the products as they become more affluent. Overall, the net income elasticity for pistachios, regardless of their origins, remains positive as expected.

Turning to the cross-price effects, we find from Table 2 that pistachios from the two origins are highly substitutable. We also find that pistachios substitute with other tree nuts from distant origins but complement to other nuts from surrounding regions. For example, US pistachios are substitutes with Turkish hazelnuts but complements to US almonds. Similarly, Iranian pistachios are substitutes with US almonds but complements to Turkish hazelnuts. The complementarity is unexpected and possibly because tree nut exporters to the EU are clustered by region (e.g. Middle East cluster versus North America cluster) and source various tree nuts within each region.

We attend to the food safety effects in Table 2. In particular, we focus on the impacts on US pistachios because the estimated effects on Iranian pistachios are not statistically significant. We find that EU imports of US pistachios are hindered by aflatoxin incidents involving the US nuts but stimulated by similar problems traced back to the Iranian nuts. To put the estimated elasticities in perspective, ten more food safety alerts targeting US pistachios reduce EU monthly imports of US pistachios by 167 tons, while ten more alerts with reference to Iranian pistachios promote EU imports of US pistachios by 200 tons a month. The finding lends support to the hypothesis that the management of food safety risks, among other non-price factors, has contributed to the success of US pistachios in international markets.

Sensitivity analysis: short-run versus long-run implications

Insofar we implicitly assume away imperfect information, rigidity of contracts, or other market constraints that slow down the adjustment of monthly decisions made by EU importers. To allow partial adjustment, we conduct an alternative analysis featuring the dynamics of trade activities by using the import volume in the previous month as an additional control variable. As a side benefit, the inclusion of the import history allows us to explore the long-run implications of food safety incidents.

Specifically, we re-estimate the system Equation 1-2 with the endogenous price of Iranian pistachios and with the import history as an extra control variable. For brevity, we only report the short-run elasticities and long-run elasticities derived from the new set of estimated coefficients. In particular, Table 3 displays the short-run results and Table 4 presents the long-run counterparts.

As shown in Table 3 and Table 4, the elasticities are generally larger in the long term than in the short term, because current import volume is positively correlated with past import flow. The baseline results in Table 2 are more comparable with the long-run effects in Table 4. Nevertheless, the control of import history alters the statistical significance of food safety incidents. One plausible explanation is that import history already conveys information about food safety risks to a certain degree.

[20] For instance, Kris-Etherton *et al.* (2008) report that regular consumption of tree nuts helps prevent coronary heart disease.

Table 3. Estimated elasticities for EU imports of pistachios: short-run results.[1,2]

	Import quantity of US pistachio	Import quantity of Iranian pistachio
Import price of US pistachio	-0.304** (0.136)	0.473** (0.216)
Import price of Iranian pistachio	0.267** (0.122)	-1.862*** (0.368)
EU income	1.872*** (0.572)	-1.497* (0.828)
Import price of US almond	-0.193** (0.085)	0.479*** (0.143)
Import price of Turkish hazelnut	0.235* (0.120)	-0.474** (0.202)
Frequency of aflatoxin incidents, traced to US	-0.057 (0.037)	-0.120** (0.060)
Frequency of aflatoxin incidents, traced to Iran	0.260* (0.147)	0.419* (0.235)

[1] To reflect recent market trends, all elasticities are evaluated at the sample means in the period of marketing year 2010/2011 and 2011/2012.

[2] Standard errors are in parentheses; *, **, and *** denote significance levels of 10, 5, and 1%.

Table 4. Estimated elasticities for EU imports of pistachios: long-run results.[1,2]

	Import quantity of US pistachio	Import quantity of Iranian pistachio
Import price of US pistachio	-0.697** (0.320)	1.065** (0.480)
Import price of Iranian pistachio	0.610** (0.281)	-4.190*** (0.607)
EU income	4.287*** (1.147)	-3.368* (1.798)
Import price of US almond	-0.441** (0.184)	1.078*** (0.302)
Import price of Turkish hazelnut	0.538** (0.262)	-1.066** (0.447)
Frequency of aflatoxin incidents, traced to US	-0.130 (0.082)	-0.269* (0.143)
Frequency of aflatoxin incidents, traced to Iran	0.596* (0.324)	0.942* (0.557)

[1] To reflect recent market trends, all elasticities are evaluated at the sample means in the period of marketing year 2010/2011 and 2011/2012.

[2] Standard errors are in parentheses; *, **, and *** denote significance levels of 10, 5, and 1%.

5. Conclusions

The United States has surpassed Iran as the largest pistachio exporter to Europe. In this article, we provide econometric evidence that the success of the US pistachio industry is partially attributable to the improved management of food safety hazards including aflatoxin risks. By estimating EU imports of pistachios from January 1999 to December 2012, we show that more aflatoxin alerts targeting US pistachios reduce EU monthly imports of US pistachios, while similar alerts concerning Iranian pistachios incentivize Europe to import more US pistachios.

Our case study highlights the distributional effects of food safety policies. In particular, food safety standards and regulations are likely to put food exporters in developing countries at a disadvantage in international markets. Capital and technical assistance to producers and processors in poor nations are necessary for them to further integrate into the global market where the demand for food safety continues to rise.

Future research in tree nuts can be promising in several directions. First, a demand analysis at the retail level has the potential to help agribusiness stakeholders improve their marketing strategies. It would also be interesting to investigate how consumers respond to the health benefits associated with tree nuts. In addition, the growing market for tree nuts might put a downward pressure on the market for peanuts. A relevant analysis is much needed to better inform peanut farmers in least developed countries.

Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2016.0090.

Table S1. The price difference of US and Iranian pistachios.
Table S2. Summary statistics of variables.
Table S3. The Dickey-Fuller tests for EU imports of pistachios.
Table S4. The Hausman-Durbin-Wu test for the exogeneity of pistachio prices.

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