Changes in aflatoxin standards: Implications for EU border controls of nut imports

Abstract

Food safety concerns about the risk of aflatoxin (AF) contamination have been growing in many regions, particularly in the EU. To protect consumers from health risks, the EU has established strict standards for maximum acceptable AF levels in food products. The EU's AF standards have changed several times. This article examines the Rapid Alert System for Food and Feed (RASFF) database, which contains notifications on border controls on AF levels in tree nuts and peanuts. A count data model was used to analyze the impact of political economy considerations, past alerts and path-dependence effects on RASFF border controls. Policy changes, including the harmonization and relaxing of EU's AF standards, significantly affected the frequency of border controls, with diverse effects among exporting countries. It is believed that the present study provides some insights to the modeling of food standards for explanation or forecasting purposes.

Keywords: Aflatoxins, Market access, Non-tariff measures, Nuts

Introduction

Traditional agri-food trade policies such as tariffs have been disappearing, yet technical and regulatory issues are increasingly coming under scrutiny. A prime example is the debate over non-tariff measures (NTMs). Public concerns about food-related health risks and suitable sanitary standards have been rising (Pinstrup-Andersen 2000), particularly in Europe (Nielsen and Anderson 2000). The phasing-out of tariffs has also raised concerns about the use of NTMs as tariff substitutes to protect domestic production (see WTO 2012, for a thorough discussion).

Scholars have extensively analyzed the trade impacts of NTMs, principally using gravity-type models (Xiong and Beghin 2014; Ferro et al. 2015). However, explaining the occurrence of NTMs based on standards (standard-like measures) is an emerging research area. While some scholars have addressed this issue from political economy approaches (e.g. Swinnen 2010, 2016; Beghin et al. 2015), few empirical analyses have identified the conditions that influence standard-like measures. To fill this research gap, this study examines the factors that influence the application of certain NTMs, specifically sanitary and phytosanitary (SPS) measures.

This study focuses on border controls of aflatoxins (AFs) in a highly problematic group of products: nuts. The model presented in this study is based on political economy considerations. The model was designed to determine the extent to which standard enforcement responds to economic pressures or reflects scientific awareness and the exporter's reputation in terms of safety. We studied how economic and political variables affect standard enforcement in the EU when different AF standards apply. We examined a period of tightening of standards and a period of relaxing of standards. Our model assessed the impact of two major changes to EU regulations: the harmonization of AF standards circa 2000 and the adjustment of AF standards after 2009 to converge with the standards in the Codex Alimentarius (Codex).

By considering path dependence on previous border controls, we dynamically modeled the influence of political economy considerations. Path dependence (i.e. history matters) in border controls has been studied in previous analyses of NTMs in the US (Jouanjean et al. 2015) and in the EU (Tudela et al. 2016). Both studies concentrate on a broad set of imported food products. The first study underlines how the odds of a country to experience import refusals by US is also affected by refusals on neighboring exporters' shipments. The second study addresses how the border behavior in the EU differs among Member States. Nevertheless, it is cumbersome to assume, as both studies do, a common enforcement pattern for a broad group of food products and for all kinds of SPS related issues. We propose in the present study to further constrain the analysis to investigate the determinants of enforcement of standards related to a more specific, though still relevant, sanitary issue. For this we chose the aflatoxin problem in a specific group of food products, nuts.

Assessing how AF events affect border controls at the EU is of interest of nut[1] producers who export to the EU in order to avoid export losses and guarantee market access (Diaz Rios and Jaffe 2008; Wu et al. 2004; Wu and Guclu 2012). AF contamination can directly increase the likelihood of rejection at the border and restrict nut imports.

Disagreements exist over the consideration of AF standards as NTMs. First, AF contamination is difficult to avoid and monitor. According to Dohlman (2003), detection and control of the fungi is a continuous concern from the production to the processing stages. Second, AF standards vary greatly across countries. This variation reflects the absence of scientific criteria when setting new standards. Finally, perceptions of health risks depend directly on producing countries' economic development and income –see findings in Li et al. (2014) on the adoption of more stringent MRL in countries with higher GDP per capita- and on a product's susceptibility to contamination.

The controversy extends to the ways that EU Member States apply standards on AF. Before 1998, each EU member state had its own AF standards for foodstuff imports. The European Commission (EC) then began harmonizing maximum allowable AF levels in edible nuts and dried fruits. By 2003, the EU had harmonized AF standards for tree nuts, establishing a MRL of 4 μg/g. This change led to concerns among nut exporters about whether the new standards would alter trade patterns. Many exporters to the EU claimed that the new standards constituted unjustifiable trade barriers and violated the Agreement on Sanitary and Phytosanitary Standards (WTO, 1999). The Codex offered revised AF standards that were more relaxed than the EU standards (Henson et al. 2000).

[1] The term nuts in this paper refers to almonds, peanuts, Brazil nuts, cashews, chestnuts, hazelnuts, macadamias, pecans, pine nuts, pistachios and walnuts.

In 2009, the European Food Safety Agency (EFSA) suggested that public health would not be adversely affected by increasing the MRL for AFs from 4 μg/kg to 10 μg/kg for tree nuts, thereby relaxing the previous standards.

This study examined data on food notifications and alerts lodged with the European Commission's Rapid Alert System for Food and Feed (RASFF). This database enables the rapid exchange of information about responses to risks that relate to food or feed that is imported to the EU. We considered the number of RASFF notifications referring to AF actions by EU Member States to be a direct measure of the incidence of NTMs. The RASFF has been used to analyze the impact of SPS measures on agri-food trade. Focusing on EU imports, Kleter et al. (2009) evaluated RASFF notifications to present emerging trends in food safety problems. Jaud et al. (2013) also used the RASFF database to gather notifications for 146 exporters to the EU and assess the geographical concentration of EU agri-food imports. Kallummal et al. (2013) used the RASFF database to study the impact of EU food safety measures on trade flows between South Asian countries and the EU. In a recent paper, Xiong (2017) also uses RASSF to model the demand of imported pistachios at the EU, with the frequency of AF alerts being an explanatory variable.

AF-related issues are a common reason for import notifications by EU Member States recorded in the RASFF database (RASFF 2002, 2015). Otsuki et al. (2001) analyzed the way changes to AF standards affect the trade flows of peanut products, suggesting that 10% tighter AF standards in the EU would decrease edible peanut imports by 11%. Later, Xiong and Beghin (2012) provided an ex-post assessment of the harmonization and tightening of EU maximum residue levels (MRLs) on aflatoxins in 2002, finding a negligible net effect on African exports. Both papers on aflatoxins measured the impact on trade flows by using gravity-models, but they did not provide a direct measure of the NTM enforcement and its determining factors as we intend in the present study. We propose a model based on political economy considerations to assess how recent changes to AF standards for EU imports of nuts affect the incidence of NTMs measured directly through a notification count at the EU border.

In the following section, a review of the principal AF regulations on nut imports to the EU is carried out. Later, a conceptual framework is proposed and leads to a model specification that explains and estimates the impact of regulatory changes on the RASFF notification count. We finalize with the discussion and the concluding sections. A framework to explain RASFF notifications is proposed. Although such framework is applied to the aflatoxin case, it can easily be extended to the exploration of other food safety issues.

Aflatoxins and nuts in the EU

The EU is the biggest importer of edible nuts in the world. In terms of value, the largest importers of edible nuts in the EU are Germany, the Netherlands, Italy and Spain, which accounted for 70% of EU imports in 2015. About 40% of EU imports come from just two countries: the USA, which provides mainly almonds and walnuts, and Turkey, which provides mainly hazelnuts. In 2015, almonds had the highest import value, with 41% of the total, followed by hazelnuts (22%), walnuts (14%) and cashews (9%).

The EU edible nut market has two segments: the agri-food industry and end consumers. In the EU, most edible nuts are used by the food processing industry. All packaging and processing for edible nuts is done in the EU. Supermarkets and the food service sector dominate the sale of nuts to end consumers in all EU member states. The EU produces only 8% of tree nuts, yet it is the second largest consumer of tree nuts in the world – after North America – and is responsible for 25% of global tree nut consumption. In 2015, North America was the largest producer of tree nuts, followed by Asia and the Middle East. Tree nut and peanut export volumes have grown in recent years. High AF levels in nuts and numerous alerts and rejections at EU borders, however, threaten to break this positive trend.

Natural AF contamination of nuts is unavoidable, yet it poses a major challenge to nut safety and quality. AFs are natural substances that are produced by the fungi *Aspergillus flavus* and *Aspergillus parasiticus*. At the right temperature and humidity, these fungi contaminate foodstuffs, particularly peanuts, dried fruit, tree nuts, spices and cereals (Strosnider et al. 2006). AFs can contaminate these foodstuffs at any stage of the value chain, especially if storage and drying facilities are unsuitable. The most toxic and most common AF is B1, which generally affects peanuts, tree nuts, Brazil nuts, pistachios and walnuts (FAO-WHO, 1997). AF risk affects 4.5 billion people worldwide, with chronic exposure through their diet. Exposure to aflatoxins is known to cause various forms of cancer and even death (US Centers for Disease Control and Prevention 2004; Emmott 2012).

In developing countries, AFs are a major problem that can severely affect the economy. To meet the EU's strict AF standards, many countries export their highest-quality foods and keep contaminated products, exposing their citizens to the risk of AF contamination. There is controversy surrounding the benefits of tightening the EU's standards. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) analyzed the potential consumer health impact of AFs at two levels: 10 parts per billion (ppb) and 20 ppb. The tightening of standards from 20 ppb to 10 ppb in EU member states was estimated to decrease the population risk by just two cancer deaths per year per billion people.

In 2002, the EU formally adopted a unified MRL policy on AF contaminants (European Commission 2001, 2002). In December 2006, the EU modified the harmonized MRLs for certain contaminants in foodstuffs but kept the same policy regarding AFs (European Commission 2006). The EU's harmonized AF standards were more stringent than the Codex international standards recommended by the Food and Agriculture Organization (FAO) and World Health Organization (WHO). First, the EU policy targeted specific AF compounds. The EU policy not only set an MRL for total AFs (as in the Codex), but also imposed an MRL on AF B1, the most toxic compound in the AF family. Second, EU MRLs were much lower than Codex MRLs. Nut exports to the EU were thus heavily affected by these regulations.

The EU officially amended the AF MRLs for tree nuts at the meeting of the Standing Committee on the Food Chain and Animal Health on 15 October 2009. The EU aligned its MRLs with Codex MRLs for total AFs in ready-to-eat almonds, hazelnuts and pistachios (10 ppb) and those destined for further processing (15 ppb). The frequency of import controls also decreased for certain products from certain origins (Iranian pistachios and US almonds).

RASFF data can be used to monitor regulatory changes. RASFF supplies complete information regarding food border measures released by EU Member States. RASFF notifications are the reports of any risk to human and animal health found in food or feed and of the actions that Member States take to manage the problem. RASFF notifications become indicators of standard-like NTMs (RASFF 2013).

AFs are the hazard category with the highest number of RASFF notifications. In 2003, the RASFF published 695 notifications on AFs in traded nuts. Following EU harmonization, the number of notifications tripled with respect to the number of notifications in 2002 (Figure 1). After 2009, notifications decreased considerably with respect to the previous three years. This might reflect legislative changes and the corresponding compliance of imported nuts.

Figure 1

Since RASFF records began (1998–2015), the products that have received most notifications have been pistachios (2,972 notifications), peanuts (2,381), almonds (905), pecans (178) and Brazil nuts (119). Over 37% of nuts that were flagged by notifications were rejected at EU borders. About 60% of total notifications were information notifications. Although alerts represented only 4% of notifications, they can be considered activators of further actions or controls. Figure 2 illustrates considerable dispersion and heterogeneity across countries that export tree nuts and peanuts to the EU. Iran and Turkey had the most notifications, receiving half of all notifications between 1998 and 2015. China received 13% of notifications, the US 9%, Argentina 6% and Brazil 5%. As we can see in the same figure, the relevance of an exporter as a target of notifications is not related to its volume forwarded to the EU. This suggests the interest to further understand the determinant factors of their controls, in addition to merely food safety issues.

Figure 2

Conceptual framework

RASFF notifications indicate concern about ‘a serious direct or indirect risk to human health’. An increase in the number of notifications, however, may owe to more checks or stricter applications of standards, which may relate to practices, inspection styles and perceptions of risk (May and Winter 2000; Versluis 2007). Moreover, political economy considerations may encourage national authorities to take control measures and issue RASFF notifications.

We propose a model to explain the count of RASFF notifications on AFs in EU imports of a product *i* originating in country *j* in year *t* ($N_{i,j,t}$). The model is able to assess the impact of critical regulatory changes, particularly the harmonization of AF standards across EU member states (2002) and the regulatory convergence with Codex standards in 2009.

RASFF notifications relate to a concern about ‘a serious direct or indirect risk to human health’. However, the count of RASFF notifications can be relatively high due to a greater number of checks and a practical leeway in the food safety regulation enforcement. When food inspectors take action, they are required to immediately report the RASFF system through different types of notifications on the event and measures taken.[2] If necessary, adoption of emergency measures could lead to binding EU measures (such as analytical tests, compulsory controls, import prohibition, etc.).[3] We can therefore analyze the conditions that influence border authorities to take control measures and release RASFF notifications.

The theoretical framework was developed using a political economy approach. This approach was based on the Grossman-Helpman model of political influence (1994), which has been used to model food standards (Swinnen and Vandemoortele 2011) as well as health standards and trade (Vigani and Olper 2013). We assume that the public administration – here, the European Commission and the national bodies responsible for controlling food imports – enforces standards by carrying out border controls, by taking into account consumer and producer concerns, which are represented through political economy influences, including consumers and producers.[4] Table 1 summarizes the variables that we included in the model to explain the number of AF-related RASFF notifications.

[2] Commission Regulation (EU) No 16/2011 of 10 January 2011 laying down implementing measures for the RASFF.

[3]Article 53 of Regulation (EC) No 178/2002 (‘General Food Law’).

[4] While nut production is not massive in the EU it is significant enough to explore domestic producers’ interests, even for pistachios and peanuts. According to FAOSTAT, peanut production at the EU accounted for 3,832 tons in 2016, with similar values in previous years. For pistachios, FAOSTAT reports 12,214 tons for 2016. EU’s almond production was 296,000 tons for 2016.

Table 1

To consider factors reflecting consumers' awareness, we used alerts reported in the RASFF database to measure consumer risk. RASFF alerts are events communicated at the EU markets that require rapid action because of a serious health risk in a food or feed already present in the market (EC Regulation XX/2011). Alerts refer to products that member states have withdrawn from the market (A_i). Past alerts in one or several Member States serve as a warning or emergence indicator that can trigger further control measures at the EU border. We hypothesize that the appearance of internal alerts in year *t-1* will represent a push for an increase in RASFF notifications in year t.

Consumers' concerns are also affected by the scientific evidence on AF-related problems (S). For this study, we built a scientific awareness index based on Smith et al. (1988) who measured the number of articles that are published on the topic of interest in each period. For each year between 1998 and 2015, the index provides a count of scientific articles and references (supporting and non-supporting) that were published that year and that addressed AF-related problems in the EU nut trade. Using this index, we were able to study the way scientific research affected EU border controls of imported tree nuts and peanuts. This index signaled EU citizens' awareness of the health impacts of AF contamination[5]. Actual consumer concerns may also be shaped by the volume and origin *j* of imports in each HS-6 category *i* ($M_{i,j}$).

As for producers, we assumed that AF standard implementation is also affected by levels of imports and by EU production (Q_i) of each nut, which may intensify producers' lobbying in the present period.

[5] Alternative approaches for measuring scientific awareness would be to consider the comparative weight of favourable versus unfavourable articles on a given issue (Brown and Schrader, 1990; Chern and Zuo, 1997) or the count of newspaper articles (Hassouneh et al., 2012). We opted by Smith et al.'s index, which may be correlated with the awareness of the aflatoxin problems.

As for other factors affecting $N_{i,j,t}$, previous research (Jouanjean et al. 2015) suggests that countries that are more developed in terms of *per capita* GDP (*pcGDP*) are less likely to fail an SPS control because their pre-export facilities are more developed.[6] Finally, we tested the effects of tariff levels on the notification count. Bagwell and Staiger (2001) and Ederington (2001) suggest that policy substitution might occur. Countries might implement or strengthen NTMs as an alternative protection mechanism if tariffs are reduced. MFN tariffs applied by the EU on nut imports have been typically low compared to other agricultural commodities but preferential agreements have further lowered their levels during the studied period. Applied tariffs (most-favored nation or preferential, depending on the case) were considered in the model to control for this effect.

Dynamic explanations of RASFF notifications were considered in the model. We tested the hypothesis that the history of member states' actions significantly influences present control measures. This hypothesis has been suggested by other authors in broader contexts (Baylis et al. 2009; Jouanjean et al. 2015) but we wish to test it for the case of the specific AF problem. Accordingly, we tested whether the AF notifications issued in one year may affect the likelihood of future notifications. This path dependence of RASFF notifications may reflect precautionary behavior by an EU member state based on risks in previous periods or the need for further controls to re-establish confidence until the product meets the appropriate standards. Likewise, persistent control measures might reflect negative perceptions of foreign products following notification of a risk or food crisis. Such perceptions may be product specific but may also result from spill over effects when several notifications concern the same product origin (i.e. the exporting

[6] Per capita GDP is introduced here as an approximation to the availability of domestic pre-export facilities that prevent failing into foreign SPS regulations. Other indicators such as "trading across border" produced by the World Bank are not suitable as they capture all the border regulations that burden imports and exports, while we are aiming at catching a positive regulation to exports.

country's questionable reputation).[7] Thus, we assumed that notifications in period *t* are affected by decisions taken in the previous period. We hypothesized that the number of product notifications for period *t* ($N_{i,j,t}$) is path dependent on the number of previous product notifications ($N_{i,j,t-1}$) and the reputation of the exporting country. This reputation is related to the total number of notifications received in previous periods ($N_{j,t-1} = \Sigma_i N_{i,j,t-1}$), which can influence current border controls for a particular product or HS-6 category.

In short, we assumed that, given a set of covariates (X), the expected notification count $\mu = E(N_{i,j,t} | X)$ for product *i*, exporter *j* and period *t* is predicted by equation 1

$$\mu = \exp[\underbrace{\beta_0 + \beta_1 N_{i,j,t-1}}_{\textbf{\textit{Product notifications}}} + \underbrace{\beta_2 N_{j,t-1}}_{\textbf{\textit{Country reputation}}} + \underbrace{\beta_3 A_{i,j,t-1}}_{\textbf{\textit{Product alerts}}} + \underbrace{\beta_4 ln\, S_t}_{\textbf{\textit{Scientific awareness}}}$$

$$+ \underbrace{\beta_5\, ln\, pcGDP_{j,t}}_{\textbf{\textit{Per capita GDP of the exporting country}}} + \underbrace{\beta_6 ln\, M_{i,j,t-1}}_{\textbf{\textit{Import level}}} + \underbrace{\beta_7 ln\, Q_{i,t-1}}_{\textbf{\textit{Production level}}} + \underbrace{\beta_8 T_{i,j,t}}_{\textbf{\textit{Tariffs}}} + \underbrace{\delta_i + \delta_j}_{\textbf{\textit{Fixed effects}}}]$$

Eq. 1

where δ_I and δ_j are fixed effects for product *i* and exporter *j*, β_1 is a path-dependence parameter and β_2 accounts for the exporting country's reputation based on the number of notifications concerning that country. We expected coefficients β_1 and β_3 to be greater than 0, which would imply a positive response of current notifications to previous controls and alerts. Note that alerts correspond to foodstuffs in the market that present a serious risk and require rapid action. When an alert appears in year *t - 1*, we would expect the number of border controls to increase in year *t*. β_6 and β_7 were also expected

[7] We adopted the reputation concept used by Jouanjean et al. (2015), who drew on Tirole's (1996) definition of collective reputation as the influence of a group's members to predict individual future behaviour.

to be greater than 0 because larger imports and domestic production should increase consumer and producer awareness, which should lead to more frequent border controls. β_2 might be positive or negative because it reflects not only border control response to an increase in the number of notifications, but also exporters' efforts to improve compliance, which should reduce the number of notifications. We expected β_5 to be greater than 0 because higher per capita GDP should mean better quality control in the exporting country. β_8 was expected to be less than 0 assuming policy substitution of NTMs for tariffs. Finally, β_4 was also expected to be greater than 0 because border controls should be more likely when scientific awareness of problems related to AFs in nuts is greater.

The impact of regulatory changes was analyzed using two dummy variables, d_1 and d_2. The dummy d_1 indicated the period 1998 to 2001, before AF standard harmonization (d_1 = 1 for t < 2002 and 0 for t ≥ 2002). The dummy d_2 indicated the period 2010 to 2015, after convergence to Codex standards (d_2 = 0 for t < 2010 and 1 for t ≥ 2010). The model also included interactions between each dummy and $N_{i,j,t-1}$, $N_{j,t-1}$ and $A_{i,t-1}$. These interactions let us assess whether policy changes affected the path-dependence effects of past alerts on current notifications.

Data and estimation procedure

Because few studies have used empirical data to estimate the effect of the EU's AF standards on agri-food trade, we used RASFF notifications to measure border controls. This study focused on AF notifications for tree nuts and peanuts. The study covered 65 countries[8] between 1998 and 2015. Notifications were coded by HS-6

[8] Afghanistan, Albania, Argentina, Australia, Azerbaijan, Bangladesh, Benin, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Cameroon, Chile, China, Congo, Côte d'Ivoire, Croatia, Egypt, Faroe Islands, Gambia, Georgia, Ghana, Hong Kong, India, Indonesia, Iran, Israel, Jordan, Kuwait, Kyrgyzstan,

product category. The outcome variable provided the notification count by HS-6 code, country of origin and year. For the empirical analysis, we used trade data to consider annual bilateral trade volumes between 1998 and 2015. We considered notifications from only the initial 15 EU member states to explore policy changes for an invariant number of EU member states over the period under study.

Table 2 presents descriptive statistics for the variables used in our estimation. The standard deviation of almost all variables was greater than the mean, which reflects over dispersion in our dataset. In addition, the data contained a high number of zero observations (i.e. zero notifications for a given product from a given country of origin in a given year).[9]

Table 2

Poisson and binomial models have been used extensively to model count data. Negative binomial (NB) models are more flexible than Poisson regression models and cope better with over dispersion, which plagues Poisson regression models (Cameron and Trivedi 2013). Thus, NB models quantify parameters more effectively than Poisson regression models when there is over dispersion.

We also had to address the question of how to explain trade flows with zero notifications. To account for the excess of zeros, we used a zero-inflated negative binomial (ZINB) regression model (Lambert, 1992; Greene, 1994).

Two processes potentially lead to zero notifications. The first process is the absence of trade. The second process is compliance with EU food controls. Because of this double process, we filtered the effect of zero trade flows through a two-stage

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Lebanon, Madagascar, Malawi, Malaysia, Mauritius, Morocco, Mozambique, Namibia, Nicaragua, Nigeria, Pakistan, Paraguay, Philippines, Russia, Rwanda, San Marino, Senegal, Sierra Leone, Singapore, South Africa, Sri Lanka, Sudan, Syria, Taiwan, Tajikistan, Thailand, Togo, Tunisia, Turkey, Uganda, Ukraine, United States of America, Uzbekistan, Vietnam, and Zambia.

[9] In total, 75,960 observations from 6,590 notifications.

estimation (Burger et al. 2009; Reyes 2012). The first stage consisted of logit regression, which determined the likelihood of zero notifications. This stage models the probability that there is no bilateral trade at all. Variables that correlated with the probability of zero notifications, including the lagged import flows, were used in this logit regression.

The second stage consisted of regression analysis of the notification count for products with a non-zero probability of trade and therefore a positive number of notifications.[10]

This double process can be represented by a ZINB model with an extra proportion of zeros and conceptually the model classifies between observations with zero counts because there is zero trade with probability $p_{i,j,t}$ and observations with a potential positive count number, with probability (1- $p_{i,j,t}$). According to this, the observed count variable $N_{i,j,t}$ can be generated by two latent variables: $Z_{i,j,t}$ an $N^{*}_{i,j,t}$:

$N_{i,j,t} = Z_{i,j,t}\, N^{*}_{i,j,t}$

where $Z_{i,j,t}$ is a binary variable with value 0 or 1, and $N^{*}_{i,j,t}$ has a Negative Binomial distribution. Then,

$$Prob(N_{i,j,t} = 0) = Prob(Z_{i,j,t} = 0) + Prob(Z_{i,j,t} = 1, N^{*}_{i,j,t} = 0)$$

$$= p_{i,j,t} + \left(1 - p_{i,j,t}\right)\pi\left(N_{i,j,t} = 0\right) \qquad \text{Eq. 2}$$

$$Prob(N_{i,j,t} = k) = \left(1 - p_{i,j,t}\right)\pi\left(N_{i,j,t} = k\right) \quad k = 1, 2, \dots \qquad \text{Eq. 3}$$

where the NB distribution for $N^{*}_{i,j,t}$ is represented by the density function $\pi(N_{i,j,t})$ and the binary process $Z_{i,j,t}$ is modelled using logit. The following variables, all of which correlated with the probability of zero notifications, were included in the logit part of the ZINB model: lagged product notifications, lagged exporting country notifications, lagged alerts, lagged logarithm of exporting countries' GDP per capita and lagged import value.

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[10] The signs of the coefficients in the logit model are usually the opposite of those in the NB model.

Despite the suitability of ZINB modeling when analyzing datasets with excess zeros, the use of NB models should not automatically be dismissed. Cameron and Trivedi (2013) report that the ZINB model does not always fit the data better than the NB model does. We therefore applied goodness-of-fit tests to select the best model. The most common criteria for comparing models are the Akaike Information Criterion (AIC), the Bayesian Information Criterion (BIC), the likelihood ratio test and the Vuong test. Table 3 presents the values of the goodness-of-fit parameters for the ZINB and NB models. All four statistical tests indicated a preference for ZINB over NB modeling. We therefore used ZINB modeling.

Table 3

Moreover, to test the consistency of ZINB estimators a generalized-method-of-moments (GMM) estimator was applied. This technique allows accounting for endogenous predictors mainly related to dynamic panel data. Arellano– Bond two step system model was used for this purpose, although the ZINB model is advisable for count data and reflects the double process leading to potential positive count. In two-step estimation, the standard covariance matrix is robust to control for critical econometric issues, heteroscedasticity, and autocorrelation (Canarella & Miller, 2018). Furthermore the robust standard errors are obtained using the Windmeijer (2005) finite-sample correction. Results are presented in the Annex Table A.1.

Findings and discussion

Table 4 presents the results of maximum likelihood estimation of the regression parameters of the ZINB. The robust variance estimator is used for standard errors to account for any arbitrary pattern of autocorrelation within exporter as well as for unobserved heterogeneity on the conditional mean[11]. Table 5 shows the elasticities of the AF notification count with respect to one unit change or one percentage point in the model variables. Specific parameters were estimated for the period 1998–2001, before EU harmonization of AF standards, the period 2002–2009, before the harmonization of EU standards with Codex MRLs, and the period 2010–2015, after the harmonization of EU standards with Codex MRLs.

EU controls of AFs in imported nuts depended on the product history and the exporter's AF notifications. This finding implies that countries or sectors that were able to keep order were less sensitive to the failure to comply with EU standards (Diaz Rios and Jaffe 2008). These reputation effects were more relevant before EU harmonization of AF standards. This pattern was also observed for the response of current notifications to past alerts, which require immediate action by member states. This reduction in the path-dependence effects on product notifications in later periods suggests that safety controls were increasingly systematic and depended less on reputation or past controls. Country reputation effects (on variable N_{jt-1}) were significant and negative, indicating that exporting countries reacted to an increase in notifications, probably by shifting exports to other destinations or strengthening subsequent export controls. Again, such reactions were more pronounced before EU harmonization of AF standards.

The significant negative elasticity of the notification count with respect to per capita GDP suggests that development is linked to greater capacity to comply with EU standards, although absolute value of this elasticity was low. Similarly, notifications were positively affected by previous production and import values. This result is consistent with the hypothesis that producers' concerns affect import controls, although with low

[11] The GMM estimators in the annex, without considering the double process that explains notifications, show the expected signs similar to the ZINB coefficients. However, scientific awareness has an opposite effect compared to ZINB coefficient. GMM confirms a significant alerts' impact on product notification.

elasticity. Interestingly, the elasticity of the notification count with respect to the number of scientific references was significant. A 1% increase in scientific references that discuss EU food standards implied a 4.81% increase in the AF notification count. Also consistent with the hypothesis was the negative sign of the variable related to the applied tariffs, which implies the existence of policy substitution, which is in line with recent evidences that point that policy substitution may occur both for import protection and in response to an increase in the demand for regulation (Beverelli et al 2014; Li et al 2014).

Table 4

Table 5

Table 6 supplies a simulation of the non-implementation of Codex regulations, taking the period 2013 to 2015 as a reference. According to this simulation, if the stricter pre-Codex scenario had been maintained, the notification count would have almost doubled with respect the observed count under softer Codex standards, with varying patterns across exporters and products. South Africa, the USA and Argentina benefit the most from the adoption of Codex MRLs. From a different perspective, Xiong (2017) also points out that success in USA pistachios' exports has in part been determined by a good management of AF food safety risks. According to Diaz Rios and Jaffee (2008), these countries proactively prevented AF contamination and established efficient certification systems. Shipments from these three countries already complied with the more flexible Codex standards before the EU adoption of Codex MRLs but did not meet the tighter MRL, so the relaxing of AF standards was effective. In contrast, Egypt, Turkey and China benefited less from weaker EU standards, perhaps because they encounter numerous safety problems even under Codex standards. Therefore, shifting to Codex MRLs benefited the most proactive countries. For countries with greater difficulties in complying with weaker AF standards, reducing the number of AF problems depended more on their own control capacity than on changes in EU regulations.

Table 6

Conclusions

Within the edible nut trade, the restrictive controls imposed by EU member states heavily affect the economies of nut producing countries. We defined and estimated a model based on political economy considerations to explain the RASFF notification count and assess the effects of changes to AF standards in the EU. It is believed that the present study provides some insights to the tricky issue of modeling standards for explanation or forecasting purposes in specific safety issues.

Our study provides an insight of the effect of changing regulations on the enforcement of food safety standards, being one of the first analysis of the effects of convergence of EU's aflatoxin standards to the Codex standard. One line of further research will be to combine such direct measure with other approaches, such as gravity models (see Xiong and Beghin, 2012), to measure the impact of new aflatoxin MRL on trade.

NTMs depend not only on alerts appeared at domestic markets and on producer concerns, but also on the export capacity of nut exporters and, most importantly, on scientific awareness of the health impact of AFs. RASFF notifications also appear sensitive to tariff levels.

Consistent with the existing literature, our study provides further evidence that product and country reputation affect the application of NTMs, which implies that past notifications on SPS non-compliance have a significant effect on current notifications. In addition, our estimates imply that events requiring rapid action (e.g. withdrawal of a product from the market) have a significant effect on the next year's notifications. The results also provide evidence that NTMs substitute tariffs in EU trade.

Using our RASFF notification count model, we evaluated the effect of changes to AF standards after isolating the effect of political economy variables. We found that countries that strived to improve the safety of their exports were likely benefit the most from the removal or the relaxing of NTMs below the tighter EU harmonized standards. Countries that made the effort to comply with previous pre-Codex standards have been largely benefited by the EU adaptation to the Codex implementation. For other countries the effect is less prominent as they already had problems to comply with Codex MRL.

Although this study sheds light on the factors that explain the enforcement of food safety controls, additional research is needed to further analyze how changes to AF standards affect nut exports to the EU. Considering standard reforms as endogenous to the model offers an interesting research opportunity.

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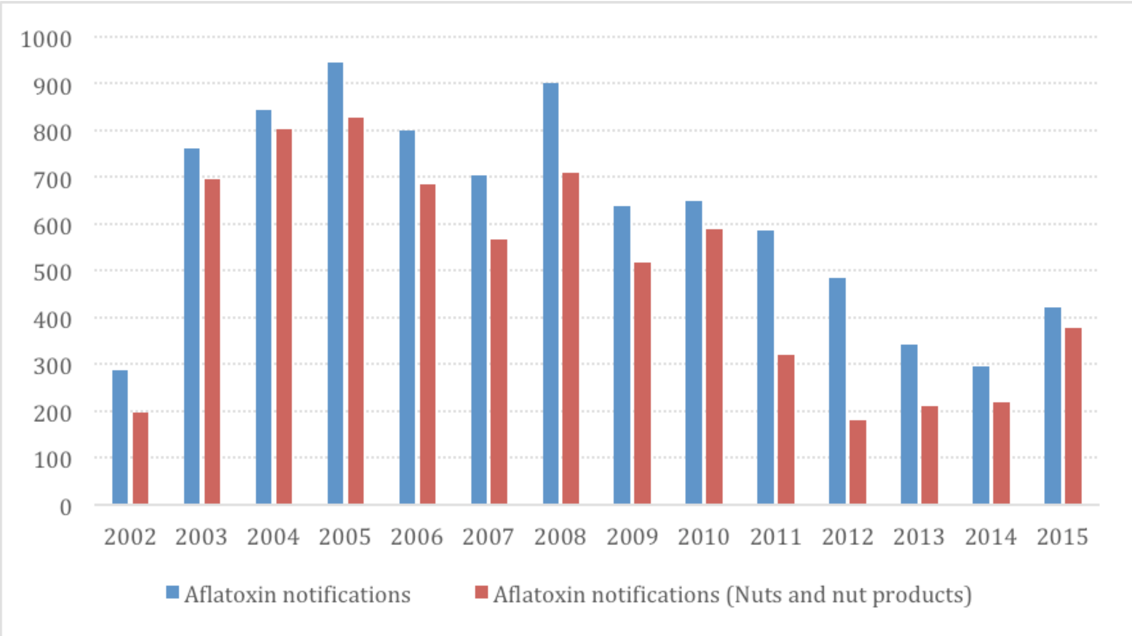
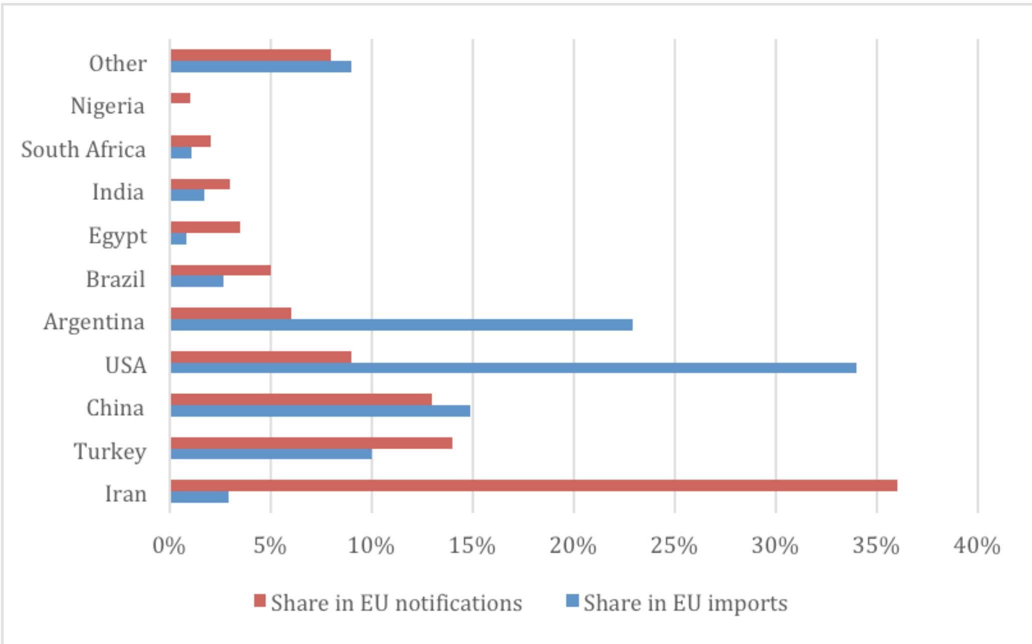
Figure 1. Total AF notifications and AF notifications of nuts and nut products (2002–2015)



Source: Authors' calculations based on RASFF annual reports (2002–2015)

Figure 2. Imports and notifications shares for the most relevant EU partners



Notes: Shares on notifications for period 1998-2015. Shares on EU-28 imports based on average quantities.

Period 2000-2015 (no data available prior to 2000).

Source: Authors' calculations based on RASSF and Comext data.

Table 1. Concepts and model variables

Concept	Model variables
Border controls on AF	Product notifications ($N_{i,j,t}$)
Capacity of exporting countries	Development level (*per capita* GDP_{jt})
Consumer concerns	Alerts ($A_{i,t-1}$) Scientific awareness (S_t) Imports from each country of origin ($M_{i,j,t-1}$)
Producer concerns	Imports from each country of origin ($M_{i,j,t-1}$) EU production of each nut ($Q_{i,t-1}$)
Path dependence effects	Previous product notifications ($N_{i,j,t-1}$) Country reputation ($N_{j,t-1}$)
Policy substitution effects	Applied tariffs ($T_{i,j,t}$)

Table 2. Descriptive statistics

Variable	Unit	Source	Mean	Std. Dev	Min	Max
$N_{i,j,t}$	Count	RASFF	0.31	7.24	0	489
$N_{i,j,t-1}$	Count	RASFF	0.30	7.23	0	489
$N_{j,t-1}$	Count	RASFF	3.94	26.21	0	490
$A_{i,jt-1}$	Count	RASFF	0.01	0.23	0	10
$M_{i,j,t-1}$	Euros (2010 prices)*	Comext-Eurostat	351.33	797.19	0	764641430.10
$Q_{i,t-1}$	Thousand Tons	Eurostat	13.74	23.39	6.47	966.71
$pcGDP_{j,t-1}$	USD (2010 prices)	World Bank	458.38	326.10	244.137	54232.65
S_{t-1}	Count of references	Google scholar	441.22	224.20	95	834
$T_{i,j,t}$	Percentage	WTO Integrated database	3.10	1.58	0	7

*The actual variable in the estimation of equation 1 is (1 + $\boldsymbol{M_{ijt-1}}$) where $\boldsymbol{M_{ijt-1}}$, if positive, is > 1000

Table 3. Goodness-of-fit parameters for ZINB and NB models

	ZINB model	NB model
AIC	23420	26942
BIC	32960.00	27209.51
Log likelihood	-11672.16	-26883.60
No. observations	75960	
Vuong test	22.76***	

Source: Authors' calculations.

Note: The Vuong test value represents the z-score statistic. The model was estimated using the R language.

Table 4. Estimated parameters for the ZINB Model

Variable	ZINB	
	Negative binomial	**Logit**
(Intercept)	**-1.504** (0.174)***	**2.58930** (0.10508)***
N_{ijt-1}	**0.021** (0.002)***	**-2.69360** (0.12514)***
N_{jt-1}	**-0.015** (0.003)***	**-0.00756** (0.00165)***
A_{ijt-1}	**0.210** (0.037)***	**0.74469** (0.31713)*
Ln ($pcGDP_{t-1}$)	**-0.003** (0.000)*	0.00013 (0.00011)
Ln (M_{ijt-1})	**0.0002** (0.0001)	**-0.00034** (0.00006) ***
Ln (Q_{it-1})	**0.005** (0.003)	**0.01582** (0.00255)***
Ln (S_t)	**0.049** (0.009)***	**0.01892** (0.00766)*
T_{ijt}	**-0.062** (0.012)***	
Dummy 1998–2001	**-1.346** (0.113)***	
Nijt.1	**0.115** (0.016)***	
Njt.1	**-0.094** (0.013)***	
A_{ijt-1}	**0.542** (0.110)***	
Dummy 2010–2015	**-0.823** (0.180)***	
Nijt.1	**0.046** (0.007)***	
Njt.1	**-0.010** (0.003)**	
A_{ijt-1}	**-0.184** (0.054)***	
Country fixed effects		
Iran	2.257 (0.180)***	
Turkey	0.774 (0.189)***	
China	-0.795 (0.197)***	
United States	2.251 (0.132)***	
Argentina	2.133 (0.147)***	
Brazil	2.376 (0.133)***	
Egypt	1.504 (0.085)***	
India	1.444 (0.111)***	
South Africa	1.400 (0.150)***	
Nigeria	2.190 (0.283)***	
Product fixed effects	***	
Log(theta)	-0.053 (0.055)	
AIC	23397.100	
Log-likelihood	-11659.550	
Num. obs.	75960	

Note: ***p < 0.001, **p < 0.01, *p < 0.05; Note: Robust standard error in parenthesis

Table 5. Estimated elasticities of the AF notification count by period (percentage change)

	Pre harmonization of EU standards	**Pre Codex compliance**	**Post Codex compliance**
Per unit change in	*1998–2001*	*2002–2009*	*2010–2015*[12]
$\mathbf{N_{ijt-1}}$	13.77	2.13	6.73
$\mathbf{N_{jt-1}}$	-11.05	-1.52	-2.56
$\mathbf{Alerts_{ijt-1}}$	77.15	21.03	2.38
$\mathbf{Tariffs\ T_{ijt}}$		- 6.20	
Per 1 % increase in			
$\mathbf{Imports_{ijt-1}}$		0.022	
$\mathbf{EU\ production_{it-1}}$		0.488	
$\mathbf{pcGDP_{(t-1)}}$		-0.029	
$\mathbf{Scientific\ references_{t}}$		4.90	
Fixed effect period	0.26	1	0.44

Source: Authors' calculations

[12] Coefficients were estimated by adding the coefficients of variables for 2002 to 2009 to the coefficients of the interaction terms for each period in the model represented by the data in Table 4.

Table 6. Average notification count (2013–2015): non-Codex scenario

Average notification count (2013-2015)		Predicted Non-Codex scenario	Observed with Codex	% impact on notification count
	South Africa	12	3	-78
	United States	67	26	-62
	Argentina	9	4	-53
	India	24	13	-45
	Brazil	19	11	-41
	Nigeria	2	1	-40
	Iran	51	35	-32
	Egypt	10	9	-13
	Turkey	55	49	-11
	China	56	54	-3
Product	Pistachios	98	51	-48
	Peanut	80	56	-43
	Almond	4	3	-25
Total		196	103	-47

Source: Authors' calculations

Annex Table A.1. Estimated parameters for the Arellano-Bond GMM Model

Variable	**Coefficient**	**Robust Stand. Error**
(Intercept)	1.439	0.998
N_{ijt-1}	0.315	0.058^{***}
N_{jt-1}	-0.002	0.002
A_{ijt-1}	3.959	0.582^{***}
Ln ($pcGDP_{t-1}$)	0.061	0.052
Ln (M_{ijt-1})	0.048	0.076
Ln (Q_{it-1})	0.194	0.100^{**}
Ln (S_t)	-0.436	0.181^{**}
T_{ijt}	-0.138	0.063^{**}
Dummy 1998–2001	-0.556	0.206^{***}
Dummy 2010–2015	-0.022	0.083
Wald chi2(10) = 579.66 Prob > chi2 = 0.000		
Arellano-Bond test for AR(1) in first differences: z = -1.15 Pr > z = 0.251		
Arellano-Bond test for AR(2) in first differences: z = 0.47 Pr > z = 0.640		
Hansen test of overid. restrictions: chi2(45) = 60.17 Prob > chi2 = 0.065		

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$