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International Sourcing Decisions in the Wake of a Food Scandal

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Abstract

This research investigates whether and how the 2013 Horsemeat Scandal has altered European food retailers' efforts to mitigate fraud in the international agri-food supply chain. We construct an econometric model that matches fraud alert data from the European Union (EU) Rapid Alert System for Food and Feed (RASFF) from 2006–2016 with annual data on bilateral trade flows. We find that—prior to the horsemeat scandal—detection of fraud along the supply chain induced a small amount of trade diversion toward third-country sources, but did not substantially affect total trade into the EU. In contrast, in the years after the scandal, the detection of fraud by international suppliers was substantially trade destructive. Detection of fraud reduced trade, not only with the country from which the fraudulent product originated, but also from third-country exporters of the same product. These findings extend beyond trade in meat products and to importing countries outside Western and Northern Europe.

Keywords: food fraud, economically motivated adulteration, EU Horsemeat Scandal, international supply chain, Rapid Alert System for Food and Feed

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"Retailers are being much more specific about the processes involved and where the meat should come from. No one wants to find themselves back on the front pages for the wrong reason." Nick Allen, Director of the English Beef and Lamb Executive, in the wake of the 2013 EU Horsemeat Scandal (Butler and Smithers, 2014).

1 Introduction

High-profile fraud scandals can alter consumer perceptions and sensitivity to food risks and result in substantial damage to the reputations of retailers and entire industries. The impacts on shareholder returns can be substantial and long-lasting. The 2013 Horsemeat Scandal in the European Union (EU) is perhaps the most notorious and high-profile food fraud event in history. In this paper, we aim to use econometric methods to investigate whether and how—in light of the EU Horsemeat Scandal—European retailers' international sourcing decisions have changed to reduce or eliminate fraud from the food supply chain to protect product and brand reputation. Our objectives are threefold: (i) we seek to understand whether efforts to control fraud are limited to meat products or apply to a wider set of food products; (ii) we seek to understand whether fraud control initiatives extend beyond the importing and exporting countries most affected by the Horsemeat Scandal; and (iii) we seek to calculate the value of lost trade resulting from fraud incidents identified under the EU Rapid Alert System for Food and Feed (RASFF).

We construct a Poisson pseudo-maximum likelihood (PPML) econometric model that matches fraud alert data from the RASFF from 2006–2016 with annual four-digit bilateral trade flow data from UN Comtrade to compare the food retailers' international sourcing response to fraud detection prior to and following the Horsemeat Scandal. Our data includes a broad set of fraudulent products and cover various fraudulent behaviors, ranging from dying various animal meats to pass as beef, to mislabeling and other misrepresentations, such as fake health certificates and products with misspecified country of origin.

Our results indicate that, prior to the Horsemeat Scandal, detection of fraud along the agri-food supply chain induced a small amount of trade diversion toward third-country sources, but did not substantially affect total trade into the EU. In contrast, in the years after the scandal, the detection of fraud by international suppliers was substantially trade destructive. The average RASFF fraud alert in our sample reduced the targeted importer-exporter-product trade flow by approximately 10%, or $460,000.[1] Detection of fraud reduced trade, not only from the country where the fraudulent product originated, but also from third-country exporters of the same product.

We find that retailer initiatives to control fraud extend beyond trade in meat products and to countries lying outside the network of countries primarily affected by the Horsemeat Scandal. Since 2013, fraud detection under the RASFF network has cost international food suppliers a total of $5.3 billion in lost trade. Approximately 80% of these losses ($4.3 billion) were experienced by exporting firms outside the countries where the fraud products originated.

This research contributes both to the literature and to policy debates on how to manage fraud in the food system. To the authors' knowledge, this is the first paper to apply econometric methods to examine the effects of food fraud on market outcomes. We highlight the role of the food retailer as a key decision maker in determining whether fraudulent foods enter the market. To the extent that retailers have the incentive to self-regulate when fraud is made known, government initiatives that identify and publicly communicate fraud information may be the most effective (and least cost) measures to mitigate fraud in the food supply chain. Moreover, our results broaden the economic effects of food fraud beyond price implications and beyond those actors directly implicated in the fraud event. The disproportionate economic impact of fraud on third-country exporters suggests the need for global—rather than local or regional—solutions to combat food fraud.

[1] Importer-exporter-product trade flow indicates the value of trade for a given product (defined at the HS four-digit level) between a given importing country and a given exporting country.

The remainder of the paper is organized as follows. Section 2 reviews the literature on the economics of food fraud. Section 3 provides a brief overview of the economic impacts of the 2013 Horsemeat Scandal on EU retailers. Section 4 explains our sampling methodology, provides a summary of the data, and outlines the estimation strategy. Sections 5 and 6 present results and consider various robustness checks. Section 7 discusses policy implications and concludes.

2 Literature Review

Food fraud is a collective term encompassing the deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging, or making false or misleading statements about a product for economic gain (Spink and Moyer, 2013). Coincident with the recent growth in public interest in food fraud, literature on the issue has expanded across a variety of academic disciplines (Smith, Manning and McElwee, 2017). From an economic perspective, the most relevant of this literature can be divided into three inter-related strands: (1) understanding suppliers' incentives to engage in fraud (Manning, Smith and Soon, 2016; Moyer, DeVries and Spink, 2017; Song and Zhuang, 2017), (2) determining the economic and public health consequences of fraud (Ali Meerza and Gustafson, 2018; Barnett et al., 2016; Spink and Moyer, 2011; Yamoah and Yawson, 2014), and (3) designing optimal regulatory response (Ali Meerza, Giannakas and Yiannaka, 2018; Manning and Soon, 2014; Song and Zhuang, 2017; Spink, 2012).[2]

There are a number of factors—both internal and external to the firm—that induce a supplier to engage in fraud (Smith, McElwee and Somerville, 2017). Among economic factors, suppliers likely have little to no flexibility in determining the price they receive for their product, as they often face take-it-or-leave-it offers with no ability or power to negotiate. As such, they may only be able to impact the net profitability of their enterprise by lowering

[2] Categorization of existing literature on the economics of food fraud into three strands is based on an informal thematic analysis conducted by the authors during the literature review process.

costs, potentially by fraudulent means (Manning and Soon, 2014; Spink et al., 2016). Song and Zhuang (2017) couch food fraud as a "market for lemons" problem: Anonymity in the modern food system leaves consumers unable to discern fraudulent products and may cause them to avoid specific product categories altogether. Macroeconomic factors can also influence food fraud opportunities (Moyer, DeVries and Spink, 2017). Manning, Smith and Soon (2016), for example, identify the 2008 financial crisis as a partial cause of the 2013 Horsemeat Scandal. McElwee, Smith and Lever (2017) and Somerville, Smith and McElwee (2015) present case studies to understand specific drivers of food fraud and examine how criminal networks perpetuate fraud in practice.

Spink and Moyer (2011) categorize the effects of food fraud into "primary" effects, classified as food safety and public health consequences, and "secondary" effects, classified as public fear and market price impacts. We do not address the issue of "primary effects" here. Within the category of "secondary" effects, Yamoah and Yawson (2014) and Barnett et al. (2016) analyze the impacts of the 2013 Horsemeat Scandal on consumer confidence and purchasing behavior. Yamoah and Yawson (2014) use supermarket loyalty card data for 1.7 million beef burger shoppers to estimate the impact of the Horsemeat Scandal on retail sales value and volume. They find a decline in retail sales value and volume across consumers of all ages in the six consecutive weeks after the first Horsemeat Scandal announcement. Barnett et al. (2016) seek to identify the core issues affecting consumers' confidence in the food industry following the Horsemeat Scandal, particularly in the meat processing sector, and to explore the impact of the horsemeat incident on consumers' purchasing and eating behavior. Using a laboratory experiment, Ali Meerza and Gustafson (2018) show that information about food fraud in one country negatively affects consumer valuation of products not only from that country, but also from other countries.

In the final strand on the design of public governance initiatives to manage food fraud, Song and Zhuang (2017) model a government-manufacturer-farmer game to identify the optimal punishments set by the government to minimize adulteration and maximize social welfare in the context of melamine contamination of milk powder. Ali Meerza, Giannakas and Yiannaka (2018) develop a theoretical model that accounts for endogenous producer quality choice and asymmetries in the probability of fraud detection to show that increases in certification costs and monitoring-punishing systems can deter fraud. In contrast to punishment, Spink (2012) and Manning and Soon (2014) recommend improving detection capabilities as a means to prevent food fraud. Kowalska, Soon and Manning (2018) explain how inconsistency in local definitions of adulteration undermine broader public initiatives to address mislabeling, misrepresentation and misbranding.

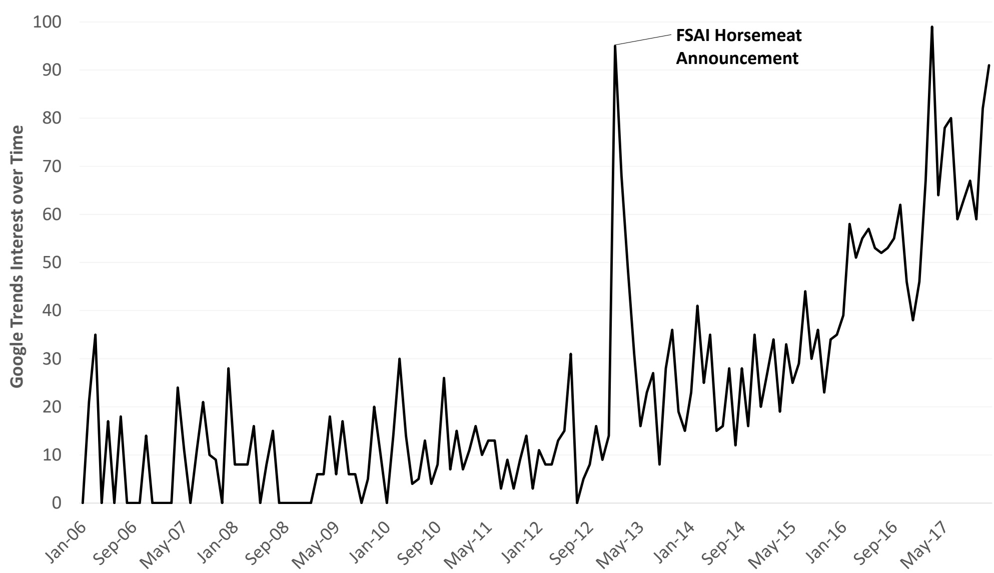
3 Background

On January 15, 2013, the Food Safety Authority of Ireland (FSAI) announced that beef products sold in Ireland and the United Kingdom (UK) tested positive for the presence of horsemeat (Telegraph, 2013). This announcement led to further fraud discoveries across France, Germany, Lithuania, Russia, Spain, Netherlands and, ultimately, exposed several organized fraud networks within and outside the EU (Manning, Smith and Soon, 2016).

Economic consequences of the scandal were swift and substantial. In the months following the FSAI announcement, more than 10 million suspect products were removed from shelves in major retailers, like Tesco, Lidl, Aldi, Iceland, and Dunnes Stores (Telegraph, 2013). Other retailers (e.g., Sainsbury's, Asda, Waitrose, and the Co-op) removed products as a precautionary measure or proactively switched suppliers (e.g., Burger King) (Telegraph, 2013). The scandal also induced long-term changes in consumers' purchasing behavior (Yamoah and Yawson, 2014). Consumers substituted away from products, brands, and foreign-sourced goods perceived as more risky (Barnett et al., 2016). Sales of red meat in the UK declined by 3% (8,000 tonnes) in 2013; sales of frozen burgers—the subject of the original FSAI announcement—fell by 7.2% (Butler and Smithers, 2014). At the same time, sales of products perceived as less risky, such as lamb and vegetarian meat substitutes, increased by more than 10% (Butler and Smithers, 2014). On January 16, 2013 (the day after the FSAI announcement), Tesco's market value dropped by 360 million EUR (Telegraph, 2013). Approximately 20% of UK shoppers say they regard Tesco less favorably than before the scandal (Barnett et al., 2016).

Several retailers stated they would substitute away from foreign-sourced products and toward local sources (Barnett et al., 2016). Tesco, for example, placed several full-page advertisements with major UK news outlets to apologize to patrons for the horsemeat contamination (Butler and Smithers, 2014). It pledged that by July 2013 it would source all chicken sold in its UK stores from British farms (BBC News, 27 February 2013). Other retailers, like Burger King, also switched suppliers proactively (Telegraph, 2013). This change in retailer behavior has led to an increase in farm assurance and country of origin schemes, such as Red Tractor, which is now used by all major UK supermarkets (Red Tractor, 2018).

Figure 1: Google Trends Interest in "Food Fraud" (January 2006–December 2017)



We hypothesize that the 2013 EU Horsemeat Scandal was a watershed moment with respect to fraud mitigation, not only for the businesses mentioned above, but for the EU food industry more broadly. Since 2013, food fraud is a growing concern in the EU and globally. Figure 1, for example, shows the Google Trends index of interest for the search term "food fraud" over time from January 2006–December 2017. According to the Figure, January 2013—the date of the FSAI announcement—saw a spike in interest in food fraud. Interest in the problem has gradually increased since the announcement. When consumers are unconcerned about fraud in the food chain and make food purchasing decisions solely on price, the least cost activity for a retailer is likely to turn a blind eye to fraudulent activity by its suppliers. However, as consumers become more aware of and concerned about the presence of fraud and associated health risks, the likelihood of lost sales resulting from the publicity generated by a food fraud incident likely serves as a motivator for retailers to increase the transparency and traceability of their foods.

4 Methodology

To formally investigate whether and how the 2013 Horsemeat Scandal has altered European food retailers efforts to mitigate fraud in the international agri-food supply chain, we match fraud detection data from the EU Rapid Alert System for Food and Feed (RASFF) from 2006–2016 with annual, bilateral trade data. We construct an econometric model to estimate the impact of a fraud alert on international trade flows prior to and following the scandal. Section 4.1 details our data collection strategy and presents summary statistics. Section 4.2 lays out the econometric model.

4.1 Data Collection and Summary Statistics

In 1979, the EU created the RASFF system to improve food safety and assist in the flow of information among member countries. Currently, the RASFF network consists of the 28 EU-member countries, plus Norway, Liechtenstein, Iceland, and Switzerland. When a public health or other risk is identified in the food or animal feed chain, a notifying country issues an "alert" to all other RASFF countries. These alerts include a description of the non-conforming product, a statement of the risk posed to food safety, and a list of the countries of origin and destination.

Between 2006 and 2016, there were over 34,000 alerts issued on the RASFF network. The vast majority of these alerts were triggered by detection of non-fraud-related food safety issues, such as food-borne pathogens, foreign objects, or spoilage. A subset of alerts (1,076) was issued on the basis of "adulteration/fraud". This subset may include both incidents where the activity was intentional and unintentional. Because we are interested in understanding supplier response to supplier behavior that was intentional and economically motivated, we retain the subset of alerts which include the word "fraud" in the subject description. We further restrict our sample to alerts issued for human (rather than animal) foods.

The final sample includes 165 alerts, including incidents ranging from fraudulent health certificates, to various animal meats dyed to pass as beef, to product certificates mis-specifying the country of origin as Korea or Japan rather than China. Because a single alert can include multiple importing countries, exporting countries, or subject products, we expand our alert data to create a unique observation for each importer-exporter-product mentioned in the alert. This yields 310 importer-exporter-product groups against which an alert was issued over our sample period. We limit our final sample to the 188 alerts where the offending product originated outside the RASFF network. This analytical step is to reflect that intra-EU trade occurs within a Customs Union, which affects not only trade flows but also consumer perceptions, and is consistent with previous literature (Baylis, Nogueira and Pace, 2010). Our fraud alert data involves 25 exporting countries, 26 importing countries, and 31 product categories matched at the 4-digit level of the harmonized tariff classification system (HS). Only one of these fraud alerts is characterized as posing a serious threat to human health.

Table 1 summarizes the alert data at the 2-digit HS level both prior to and following the Horsemeat Scandal. Comparing the pre-Scandal rate of detection with the detection rate after 2013 shows a substantial reduction in fraud incidents. Of the 188 fraud incidents identified in our sample, approximately 80% of alerts were issued prior to the Horsemeat

Table 1: Fraud Alerts by Two-Digit HS Category

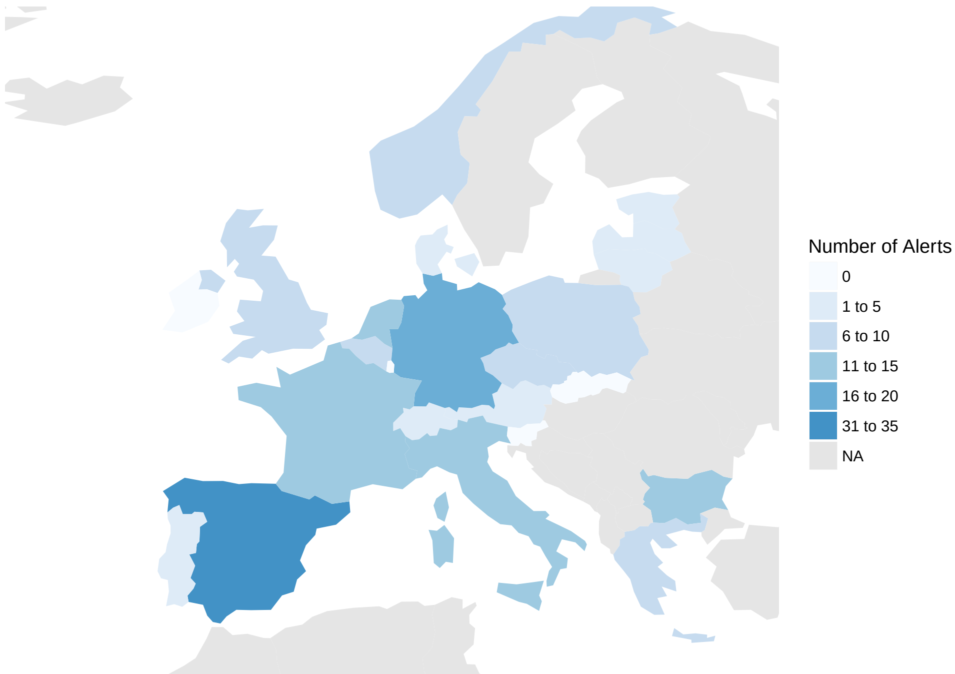
HS	Product Description	Pre-Scandal	Post-Scandal	Full Sample
02	Meat & Edible Meat Offal	26	2	28
03	Fish & Crustaceans, Molluscs	88	12	100
04	Edible Animal Products NES	3	3	6
07	Edible Vegetables & Certain Roots & Tubers	1	1	2
08	Edible Fruit & Nuts; Peel of Citrus Fruit or Melons	1	4	5
09	Coffee, Tea, Mate & Spices	1	0	1
15	Animal or Vegetable Fats & Oils	2	1	3
16	Prepared Foodstuffs & Beverages	23	1	24
17	Sugars & Sugar Confectionery	1	0	1
19	Preparations of Cereals, Flour, Starch or Milk	2	2	4
20	Preparations of Vegetables, Fruits, & Nuts	0	4	4
21	Miscellaneous Edible Preparations	1	7	8
22	Beverages, Spirits & Vinegar	0	1	1
32	Tanning or dyeing extracts	1	0	1
	Total	**150**	**38**	**188**

Scandal, suggesting fraud was detected at a rate of 21 incidents per year. Following the FSAI announcement in January 2013, 38 incidents were identified, a rate of 9.5 per year.[3] In some sense, the decreased rate of fraud detection per year runs counter to expectations. One might expect that, in light of the widespread media coverage related to the Horsemeat Scandal, customs authorities would increase the scrutiny of inspections with respect to fraud, leading to an increase in the rate of fraud detection. Industries' own response is perhaps the most reasonable explanation for this slowdown in annual RASFF fraud detection rates. Food retailers likely shifted away from sources with a higher probability of fraud following the scandal. A comparison of fraud detected in HS 02, under which the fraudulent horsemeat products were traded, is most indicative on this point. Prior to the scandal, HS 02 was the second most common fraud category, with a rate of 3.7 incidents per year. After the scandal, fraud detection in HS 02 fell to less than one incident per year. HS 03—fish, crustaceans, and mollusks—was the sector with which fraud was most frequently associated prior to and following the Horsemeat Scandal.

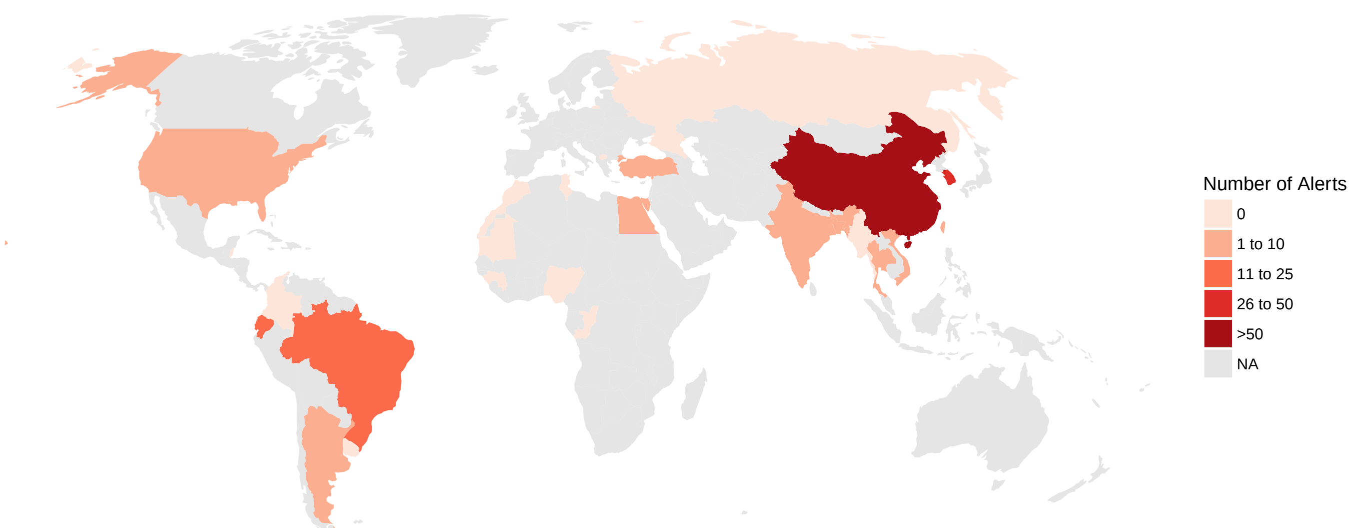
[3] The decrease in detections per year is not universal across all products. For example, product categories like edible fruits (HS 07) and prepared vegetables, fruits, & nuts (HS 20) experienced an increase in detections per year. However, overall, annual detection rates are less frequent in the years following the scandal.

Figure 2: Geographic Distribution of Fraud Alerts

(a) Importing Country



(b) Exporting Country



The maps in Figure 2 show the geographic distribution of fraud alerts. Panel (a) indicates the count of RASFF fraud alerts reported by importing country; panel (b) gives the count by attributed exporting country. As is evident from the maps, all but one RASFF country (Croatia) detected fraud over the sample period and fraud was most prevalent in Spain and Germany. Panel (b) highlights the diversity of exporting countries who engage in fraud. Our sample includes food fraud originating on every continent except Australia. In our sample, China is by far the most frequent origin country outside the RASFF network for fraudulent products.[4]

Table 2: Summary Statistics

	Pre-Scandal Sample		Post-Scandal Sample		Full Sample			
Variable	Obs	Mean	Obs	Mean	Obs	Mean	Min	Max
$Value_{iep}$	489,556	5.36	277,142	6.21	766,698	5.67	0.00	21.97
		(5.94)		(5.93)		(5.95)		
FX_X	489,556	3.08	277,142	3.33	766,698	3.17	1.54	10.34
		(2.72)		(2.77)		(2.74)		
FX_M	489,556	0.29	277,142	0.42	766,698	0.34	0.69	5.64
		(1.22)		(1.25)		(1.23)		
GDP_X	489,556	24.80	277,142	25.13	766,698	24.92	16.83	30.56
		(2.29)		(2.28)		(2.29)		
GDP_M	489,556	26.81	277,142	26.79	766,698	26.80	22.63	28.99
		(1.50)		(1.48)		(1.49)		
Own Alert	489,556	0.00	277,142	0.00	766,698	0.00	0	1
		(0.02)		(0.01)		(0.01)		
Third-Country Alert	489,556	0.03	277,142	0.02	766,698	0.03	0	1
		(0.16)		(0.15)		(0.16)		
Year	489,556	2008.99	277,142	2014.48	766,698	2010.98	2006	2016
		(2.00)		(1.12)		(3.15)		

Variables $Value$ and GDP are specified in natural logarithmic form.
Standard deviation in parentheses.

We match the fraud alert data at the 4-digit HS level with annual bilateral trade flow data (in nominal US$) obtained from the UN Comtrade database (United Nations Statistics Division, n.d.). We queried the database for all imports into RASFF countries from exporting

[4]Note that, although China has the highest number of RASFF fraud alerts in our sample, this does not necessarily imply that China has the highest incidence of fraud. China is subject to very rigorous testing requirements, and other countries not subject to the same testing regime may have equal or higher incidence of fraudulent activity.

countries outside the EU for the 44 product categories for which alerts containing the word "fraud" were issued. The final dataset contains all importer-exporter-product groups for which there was at least one non-zero trade flow over the period of observation. For these importer-exporter-product groups, we include in the dataset all zero trade flows. We include standard gravity controls for importing- and exporting-country GDP and exchange rates obtained from the World Bank. Our sample includes 31 importing countries, 185 exporting countries, 43 products, and 818,448 observations over the sample horizon. Table 2 presents summary statistics.

4.2 Econometric Model

We construct an econometric specification based on the gravity model from the international trade literature. At any time t, the value of bilateral trade (T) in product k between exporting country j and importing country i is a function of the economic "mass" of countries i and j (measured in terms of GDP), exchange rates (FX), the fraud-risk profile of the product, and a set of controls (Z). We specify the model as follows:

$$T_{ijkt} = \alpha \text{GDP}_{it}^{\beta_1} \text{GDP}_{jt}^{\beta_2} exp[\beta_3 A_{kij,t-1} + \beta_4 H_t A_{kij,t-1} + \beta_5 A_{ki\sim j,t-1} + \beta_6 H_t A_{ki\sim j,t-1} \\ \beta_7 FX_{jt} + \beta_8 FX_{it} + \theta Z_{kij}]\epsilon_{kjit} \quad (1)$$

We include two variables to quantify the effects of fraud detection on international sourcing. The first is the "Own Alert" effect of an RASFF alert (denoted A_{kij}), which measures the impact of an RASFF fraud alert on trade value within the importer-exporter-product category against which the alert was issued. Variable A_{kij} is an indicator that takes the value one in periods in which a fraud alert is issued, and zero otherwise. In addition to this "Own Alert" effect, we include a variable to measure the effect of an RASFF fraud alert on third-country exporters (denoted $A_{ki\sim j}$). The negative reputational effect of fraud detection may affect all trade in the product regardless of the country of origin. Qualitative and anecdotal evidence suggests that the Horsemeat Scandal changed consumers' relative valuation of foreign versus domestically produced foods (Barnett et al., 2016; Butler and Smithers, 2014). This third-country effect is also consistent with previous literature on the economics of food safety border rejections (Baylis, Martens and Nogueira, 2009; Jouanjean, Maur and Shepherd, 2015). Variable $A_{ki\sim j}$ is an indicator that takes the value one if an alert was issued against product k for another exporting country than j, and zero otherwise.

Because our primary question of interest is whether the 2013 Horsemeat Scandal altered importing firms' sourcing behavior with respect to fraud alerts, we create an indicator variable H_t equal to one from 2013 onwards, and zero otherwise. The interaction between H_t and fraud alert variables A_{kij} and $A_{ki\sim j}$ provides a nested specification that allows sourcing decisions to change due to the scandal. Because post-Scandal trade effects are estimated via nested parameter H, the total magnitude of these effects is the sum of the pre- and post-Scandal coefficients. Statistical (and economic) significance on the post-Scandal interaction coefficient suggests that sourcing behavior has changed as a result of the scandal.

We evaluate the effects of an alert with a single-period time lag (i.e., variables A_{kij} and $A_{ki\sim j}$ issued at time $t-1$ affect trade in time t). This modeling choice is made for several reasons. First, alerts are issued throughout the year, but our trade data is annual. Thus, the contemporaneous specification treats alerts issued at the beginning of January in the same way as alerts issued at the end of December. The lagged specification allows us to evaluate the effects of alerts issued at different times throughout the year with equivalency in the duration of treatment. A related issue is that an importing firm's response to fraud detection may not be instantaneous. Importing firms may import only seasonally or be committed to existing contracts with exporting firms. Finally, there is likely simultaneity bias between variables A_{kij} and T_{kij}. To see this, imagine that, for each unit of product k imported between countries i and j, there is a non-zero probability σ that the product is fraudulent. If σ is constant with respect to the volume of trade, an increase in the volume of trade increases the probability of a fraud alert. The lagged specification reduces—but does not cure (Bellemare, Masaki and Pepinsky, 2017)[5]—endogeneity concerns with respect to variable A_{kij} and T_{kij}.

Control vector Z includes importer-exporter-product level fixed effects and year fixed effects. The first set of fixed effects control for time-invariant relationships between importing and exporting countries, such as proximity, similar languages, and colonial relationships. It also controls for agro-ecological growing conditions in the exporting country, including climate zones and the availability of arable land, and time-invariant product demand factors within the importing country. Year fixed effects control for EU wide changes in laws or other policies affecting trade. The variation used to identify the effect of a food fraud incidence in product sourcing is, therefore, the time variation within exporter-importer-product category from 2006 to 2016.

We use the Poisson pseudo-maximum likelihood (PPML) method to estimate equation (1). Under PPML, equation (1) is estimated in its multiplicative form (Silva and Tenreyro, 2006). This method avoids many of the pitfalls associated with the standard procedure of log transformation and reduced-form ordinary least squares (OLS) estimation. Variable T_{ijkt} includes a large amount of zero trade flows, and log-transformed OLS drops all zero observations. In contrast, PPML allows for inclusion of zero trade flows. Log transformation also leads to inconsistent OLS estimation due to heteroscedasticity in the error term (Silva and Tenreyro, 2006).[6]

[5] Bellemare, Masaki and Pepinsky (2017) argue that—in cases where there exists a simultaneity bias between the independent and dependent variable—using the lag of the dependent variable changes the channel through which the endogeneity occurs. They argue that in order for the estimates to be unbiased, one must assume no serial correlation exists among the unobserved sources of endogeneity. This assumption is not testable.

[6] In equation (1), it is assumed that E[ϵ_{kjit}]=1. For the log transformation to be consistent, we need E[log(ϵ_{kjit})]=0. This requires that log(E[ϵ_{kjit}])=E[log(ϵ_{kjit})], which Silva and Tenreyro (2006) show is not true if there is heteroscedasticity in the error term.

5 Results

Table 3 presents estimation results. Column (1) contains results for the full sample of importer-exporter-product groups; columns (2) through (5) split the sample into various product, importing-country, and exporting-country groups to investigate robustness. Column (6) aggregates trade flows across importing countries to treat the EU as a single entity. Control variables for importing- and exporting-country GDP and exchange rate are generally of the expected sign across all specifications. Results for our variables of interest—"Own Alert", "Own Alert Post-Scandal", "Third-Country Alert", and "Third-Country Alert Post-Scandal"—are presented in the first four rows of the Table. We deduce the effects of the 2013 Horsemeat Scandal on industry fraud governance and broader implications for the global supply chain by comparing variable "Own Alert" with "Own Alert Post-Scandal" and variable "Third-Country Alert" with "Third-Country Alert Post-Scandal".

Turning to the primary results in Column (1) of Table 3, the coefficient on "Own Alert" is statistically insignificant and positive. This result suggests that—prior to the Horsemeat Scandal—the detection of fraud by the RASFF network did not result in a measurable impact on trade with the country from which the fraudulent product originated. In contrast, the coefficient on "Own Alert Post-Scandal" is negative and statistically significant. The detection of food fraud following the Horsemeat Scandal induced a 10.36% (-18.2% + 7.8%) reduction in trade from the targeted country. These results indicate that the 2013 Horsemeat Scandal substantially altered sourcing decisions. After the scandal, retailers are incentivized to mitigate fraud and react to instances of food fraud detected in imports to their own country by avoiding or reducing imports of the alerted product from the offending country. Prior to the scandal, this incentive was not present; we do not observe evidence of response to food fraud incidents.

The stark change in the response to fraud detection also extends to the treatment of third countries. The coefficient estimate for "Third-Country Alert" is positive and statistically significant at 99% confidence, suggesting that, prior to the 2013 Horsemeat Scandal, detection

Table 3: Impact of RASFF Fraud Alerts on International Trade Flows

VARIABLES	(1) Full Sample	(2) Excl. HS02 Product Group	(3) W & N Europe Importers	(4) All other Importers	(5) Asia Exporters	(6) EU as one Importer
Own Alert (L)	0.078	0.106*	0.080	0.096*	0.174***	0.138***
	(0.061)	(0.057)	(0.089)	(0.054)	(0.058)	(0.0460)
Own Alert Post-Scandal (L)	-0.182*	-0.205**	-0.302**	-0.162	-0.481***	-0.214**
	(0.010)	(0.098)	(0.132)	(0.123)	(0.072)	(0.108)
Third-Country Alert (L)	0.076***	0.086***	0.087**	0.078**	0.139***	0.0471***
	(0.024)	(0.022)	(0.035)	(0.032)	(0.035)	(0.0152)
Third-Country Alert Post-Scandal (L)	-0.143***	-0.144***	-0.145***	-0.170***	-0.378***	-0.101***
	(0.040)	(0.038)	(0.052)	(0.056)	(0.064)	(0.0337)
Partner FX	-8.24e-06	-8.40e-06	-1.90e-05*	1.73e-05	-1.66e-05	-9.99e-06
	(1.17e-05)	(1.20e-05)	(1.02e-05)	(1.83e-05)	(1.10e-05)	(1.07e-05)
Reporter FX	0.002*	0.002	0.005*	-0.000	0.0024	0.0226
	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)	(0.0138)
Log Partner GDP	0.474***	0.362***	0.505***	0.399***	0.550***	0.478***
	(0.090)	(0.082)	(0.116)	(0.118)	(0.113)	(0.131)
Log Reporter GDP	0.272*	0.320**	0.347*	0.887***	-0.032	-0.0379
	(0.152)	(0.151)	(0.191)	(0.199)	(0.230)	(0.416)
Observations	674,664	583,060	425,915	248,587	239,724	63,498
Number of Panel Groups	68,687	59,405	43,142	24,545	24,226	6,462

Standard errors in parentheses are clustered at importer-exporter level for columns 1–5.
Standard errors in column 6 are clustered at exporter-product level.
*** p<0.01, ** p<0.05, * p<0.1
(L) denotes lagged explanatory variable.

of fraud by one country resulted in approximately 7.6% trade diversion *toward* third-country exporters.[7]

Following the scandal, however, the detection of fraud resulted in a 6.7% contraction (-14.3% + 7.61%) in trade with third-country exporters. This result is also statistically significant at 99% confidence. These results are consistent with the findings in Barnett et al. (2016) that consumers now have less trust in foreign-produced foods and have turned to local sources. As a result of the scandal, fraud detection has shifted from a trade diversionary event to a trade destructive event. Retailers reduce imports not only from countries from which fraudulent products originate, but also from third-country exporters.

The shift away from fraud-originating and third exporting countries as a result of fraud detection and the post-Scandal destructive nature of fraud on trade are robust across a range of alternative specifications on product, importing country, and exporting country. Our first robustness check relates to the product scope of the effects discussed above. One could imagine the EU Horsemeat Scandal fundamentally altered consumer and producer sensitivity to fraud in relation to trade in meat products, but left other agri-food product markets unaffected. In column (2) of Table 3, we re-estimate equation (1) excluding trade in meat and edible meat offal (HS02). Results are qualitatively similar to Column (1). As in Column (1), the point estimate on "Own Alert" is positive (10.6%), while the point estimate on "Own Alert Post-Scandal" is negative and large in magnitude.[8] Together, the coefficients imply the post-Scandal effect of fraud detection for products outside HS02 is a 9.9% reduction (-20.5% + 10.6%) in trade with the country from which the fraudulent product originated. Findings for products outside HS02 also hold in relation to third-country effects. Column (2) results for pre-Scandal third-country trade diversion were 8.6%, compared to 7.6% for the

[7] We attribute this pre-Scandal trade diversion to retailer behavior, but one reviewer offered an interesting counter-hypothesis based on the presence of illicit chains that continue operation after detection and intentionally mis-specify the origin country for future shipments. Such a hypothesis is rooted in historically observed fraud activity, such as Chinese honey imports into the U.S. We acknowledge that such activity undoubtedly takes place in our sample, but we believe that—in the aggregate—the impact of the issue is small relative to changes in retailer sourcing behavior and likely unobservable at the country level.

[8] We note that the statistical significance on "Own Alert" in Columns (2), (4), and (5) are likely the results of the endogeneity discussed in Section 4.2 and Bellemare, Masaki and Pepinsky (2017).

full sample. After the scandal, fraud detection reduced third-country trade by a predicted 5.8% (-14.4% + 8.6%), compared to 6.7% for the full sample.

Columns (3) and (4) of Table 3 investigate whether our results are local to one or more importing countries. We hypothesize that the incentives for fraud deterrence are greatest in countries most affected by the Horsemeat Scandal and countries with the highest disposable incomes. These hypotheses appear to hold—at least in relation to the "Own Alert" effect. Scandal sourcing effects also extend to other importing regions (though effects are smaller in magnitude). Column (3) restricts estimation of equation (1) to importing countries in Northern and Western Europe.[9] Column (4) presents results for all other importing countries in the RASFF network. Consistent with Column (1), results for both country groups suggest fraud detected prior to the Horsemeat Scandal did not reduce trade with the country from which the fraudulent product originated, whereas fraud detected following the scandal had a negative, statistically significant effect on targeted trade flows. However, the magnitude of the post-Scandal trade effects differs between country groups. When the sample is limited to importing countries in Northern and Western Europe, detection of fraud induced a 22.5% reduction (-30.2% + 7.95%) in trade with the country from which the fraudulent product originated. In other RASFF importing regions, the corresponding reduction was only 6.61% (-16.2% + 9.59%). Third-country effects in Columns (3) and (4) are also consistent with the full-sample findings. Pre-Scandal effects in Northern and Western Europe and other RASFF importing countries are positive trade diversion of 8.7% and 7.8%, respectively. Post-Scandal effects are -5.8% (-14.5% + 8.7%) and -9.2% (-17.0% + 7.8%).

In Column (5) we investigate the exporting-country scope of our findings. The data limit this analysis to consideration of Asian exporters; only 12 of 38 fraud alerts after 2013 originate from non-Asian countries. Column (5) reports results for Asian countries. The direction of the estimates is consistent with those from Columns (1) through (4). However, the effects are magnified. In the wake of the Horsemeat Scandal, the "own" effect fell from

[9] These countries are Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Sweden, Switzerland, and the United Kingdom.

17.4% to -30.7% (-48.1% + 17.4%). The “third-country” effect fell from 13.9% to -23.9% (-37.8% + 13.9%).

Finally, free trade within the EU means that the country where the alert arises is not necessarily the country where the food is destined. If fraudsters believe that some border inspection points are less rigorous in terms of surveillance and application of regulations than others, they may target those less rigorous border points more than others. In column (6), we control for this by aggregating all importing country trade flows to treat the EU as a single entity. Results are robust to this specification. Following the Horsemeat Scandal, the “own” effect fell from to 13.8% to -7.6% (-21.4% + 13.8%). The “third-country” effect fell from 4.71% to -5.39% (-10.1% + 4.71%).

6 Post-Scandal Trade Impact

Because trade values (in US$) vary substantially across importer-exporter-product groups, we assess the magnitude and distribution of a single fraud incident on international trade following the 2013 EU Horsemeat Scandal as follows:

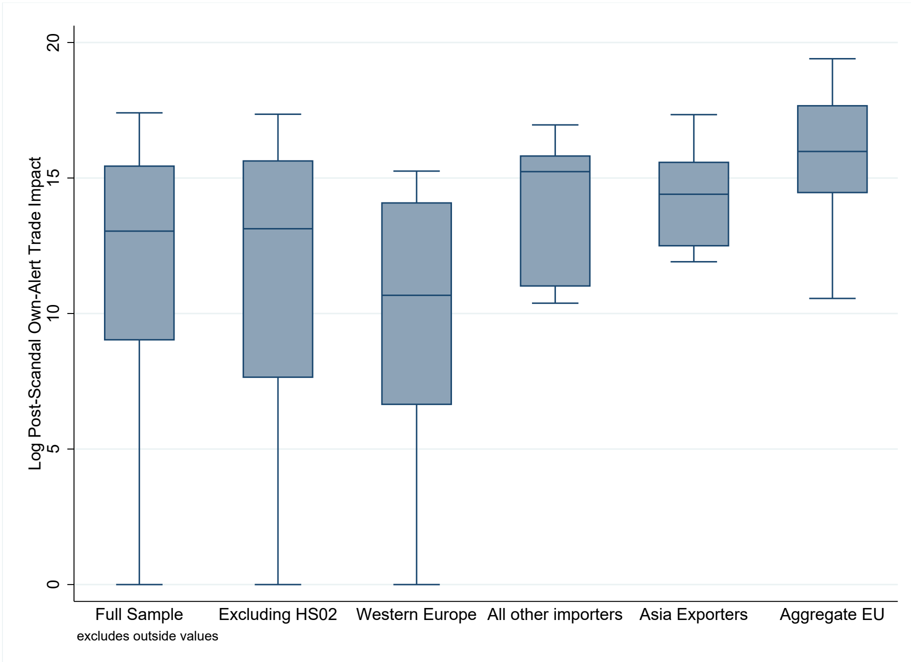
$$\hat{V}_{ijkt}^{Own} = (\hat{\beta}_3 + \hat{\beta}_4) A_{kijt} H_t T_{ijk,t+1} \tag{2}$$

$$\hat{V}_{ijkt}^{Third} = (\hat{\beta}_5 + \hat{\beta}_6) A_{ki\sim jt} H_t T_{ijk,t+1} \tag{3}$$

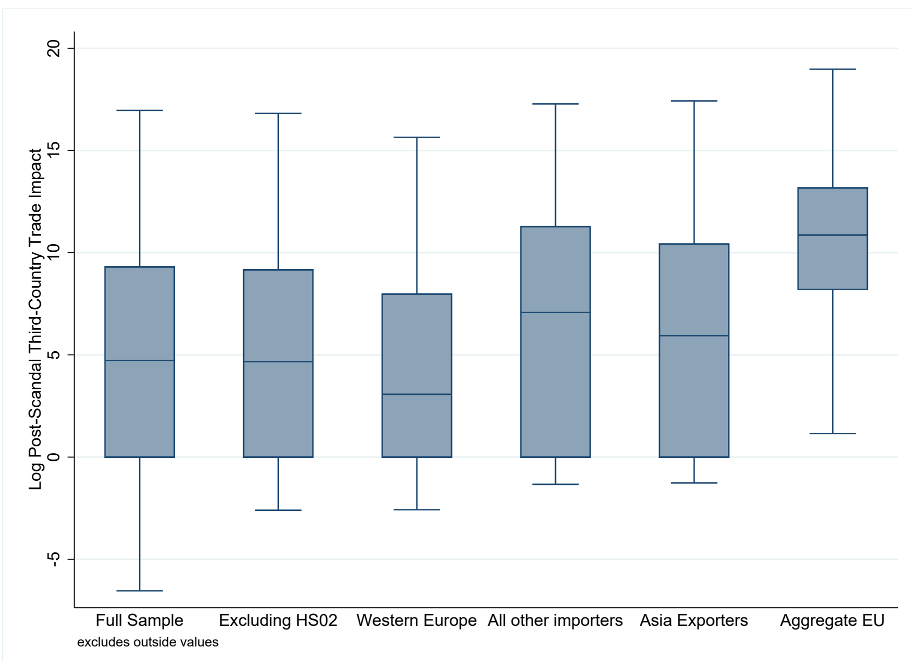
where $\hat{V}_{ijkt}^{Own}$ is the predicted value of lost trade in importer-exporter-product category ijk resulting from a post-Scandal “Own Alert” and $\hat{V}_{ijkt}^{Third}$ is the predicted value of lost trade resulting from a post-Scandal “Third-Country Alert”. All other variables ($\beta_3, \beta_4, \beta_5, \beta_6, A_{kijt}, A_{ki\sim jt}$, and $T_{ijk,t+1}$) are defined as in equation (1).

Figure 3: Post-Scandal Impact of a Fraud Detection Event

(a) "Own Alert" Impact ($\hat{V}_{ijkt}^{Own}$)



(b) "Third-Country" Impact ($\hat{V}_{ijkt}^{Third}$)



Panels (a) and (b) plot $\text{Ln}(|\hat{V}_{ijkt}^{Own}|+1)$ and $\text{Ln}(|\hat{V}_{ijkt}^{Third}|+1)$ for visual clarity. Natural log is used to re-scale values over a more-condensed range. Absolute value is used because all values of $\hat{V}_{ijkt}^{Own}$ and $\hat{V}_{ijkt}^{Third}$ are less than or equal to zero, and natural log is defined only for values greater than zero. Likewise, we add one because natural log is undefined at zero. The term "excludes outside values" signifies that statistical outliers have been included to construct the "box" and "whiskers" but are not visually depicted in the Figure.

The box-and-whisker plots in Figure 3 show the distributions of $\hat{V}_{ijkt}^{Own}$ and $\hat{V}_{ijkt}^{Third}$.[10] As shown in panel (a) of the Figure, the median "Own Alert" impact of a single fraud alert is a $460,000 reduction in trade. When product category HS02 is excluded from the analysis, the "Own Alert" reduction in trade is approximately $500,000 at the median. Western and Northern Europe appear to be especially vigilant in controlling food fraud. In addition to having a larger proportionate impact on trade (Table 3, Column (3)), fraud appears to occur predominantly in product categories with a low value of trade. The median impact of a fraud detection event is a $43,000 reduction in trade. In contrast, fraud incidents in other importing countries occur in product categories with a high value of trade. In spite of having a small percentage impact on trade (Table 3, Column (4)), an "own alert" fraud incident results in a median reduction in trade of $4.2 million. Asian exporters also experience a greater-than-average impact on trade. At the median, a single fraud incident costs Asian exporters approximately $1.8 million in lost trade. This is likely consistent with consumer perceptions of greater risk associated with Asian countries. China, for example, has had several food fraud incidents considered a severe risk to human health, such as the 2008 milk scandal.

Turning to Panel (b) of Figure 3, the "third-country" effect of a single fraud incident is extremely small for a given importer-exporter-product category. The median impact, evaluated across the full sample, is $113 in lost trade per fraud incident, as measured in equation 3. Excluding product category HS02, the impact is $108. As with the "own alert" effect, there is a dramatic difference between "third-country" effects inside and outside Western and Northern Europe. Among Western and Northern Europe importers, a fraud alert against one exporter reduces for the median third-country exporter by only $23. In contrast, the corresponding third-country effect for importers outside of Western and Northern Europe is $1,188. Asian exporters experience a third-country effect of $380 per fraud incident.

However, although the "third-country" effects for a single exporter and for a single product

[10] Note that—because estimation for the EU as an aggregate region, shown in column (6) of table 3, is not directly comparable to single-importing-country results from columns (1)–(5) of the table—we omit discussion of the aggregate EU results from this section. However, estimates are displayed in table 4.

are small on average, there are many third-country exporters affected by a single fraud alert. When effects are summed across all affected exporters, the "third-country" effects dwarf the "own alert" effects. We calculate the total cost of fraud detection on international trade following the 2013 Horsemeat Scandal as follows:

$$\hat{V}^R = \sum_{ijkt} \hat{V}_{ijkt} \quad R \in \{Own, Third\} \tag{4}$$

$$\hat{V}^{Total} = \hat{V}^{Own} + \hat{V}^{Third} \tag{5}$$

Table 4 presents these calculations. Since the 2013 Horsemeat Scandal, detection of fraud has reduced trade with countries from which fraudulent products originated by approximately $1 billion. As a result of this detection, trade with non-offending, third-country exporters has fallen by approximately $4.3 billion—more than 400% that for the perpetrating countries. Thus, the total effect of fraud detection since 2013 has been a $5.3 billion reduction in trade, about a 3% loss in the total value of trade in these product categories. Note that the estimates shown in Table 4 are not summative. For example, the impact for "Western Europe" plus impact for "All other Importers" is not equal to the "Full Sample" impact because each estimate is derived from independent regression coefficients. Nevertheless, findings hold up relatively well with comparisons across specifications.

Table 4: Total Impact of Fraud on International Trade *(million USD)*

	Own Alert ($\hat{V}^{Own}$)		**Third-Country** ($\hat{V}^{Third}$)		**Total** ($\hat{V}^{Total}$)	
Category	Affected IEP Groups	Estimated Impact	Affected IEP Groups	Estimated Impact	Affected IEP Groups	Estimated Impact
Full Sample	21	-$982	2,507	-$4,300	2,528	-$5,282
Excluding HS02	20	-$933	2,187	-$3,500	2,207	-$4,433
Western Europe	11	-$108	1,513	-$967	1,524	-$1,075
All other importers	10	-$597	994	-$4,380	1,004	-$4,977
Asia Exporters	9	-$702	809	-$4,260	818	-$4,962

Note: Estimates are derived via separate regressions (shown in Table 3) and are not summative.

7 Policy Implications and Conclusion

This research investigates whether food retailers take actions to mitigate the risk of food fraud in the international supply chain in light of increasing global concern for the issue. We match fraud alert data for years 2006–2016 from the European Union (EU) Rapid Alert System for Food and Feed (RASFF) database with bilateral trade flows into the European Union at the 4-digit product level of the Harmonized Tariff System. Our results indicate that the 2013 EU Horsemeat Scandal was a watershed event with respect to private fraud governance in the EU global food supply chain. Food retailers have changed their procurement behavior as a means to shore up brand equity and consumer trust. Prior to 2013, fraud events resulted in a small amount of trade diversion towards third-countries, but did not have a statistically significant effect on trade with the country from which the fraudulent product originated. Following the scandal, detection of fraud resulted in a substantial contraction (approximately 10%) in bilateral trade with the fraud-originating country. Since 2013, the average fraud incident reduced the value of trade from the country in which the fraud originated by almost $460,000 per year.

Moreover, fraud detection not only reduces trade from the fraud-originating exporting country, but also generates a negative externality for third-country exporters of the same product. Aggregating across exporting countries, this third-country effect dwarfs the primary effect. Since 2013, fraud events have cost countries from which the fraudulent products originated almost $1 billion and third-country exporters an additional $4.3 billion. When importers react to alerts by substituting away from source countries where no food safety or adulteration threat exists, deadweight loss to industry and society can result. Foreign export industries may be denied access to international markets and domestic consumers may be forced to pay higher food prices.

This research is not without limitations. Fraud activity that could potentially be characterized by the media as more duplicitous or posing a greater risk to human health would likely have a greater impact on trade than activity that does not. We are only able to calculate an "average" trade effect across all fraud events prior to and following the Scandal. Our data do not allow us to differentiate between different forms of fraudulent activity (e.g., economically motivated adulteration versus mislabeling). Similarly, we are unable to distinguish fraud events that pose major public health risks versus events with no short- or long-term implications for human health.

Importantly, the impact on the international market is also only a partial measure of the total social welfare effect of food fraud. As retailers move away from high-risk international sources, the increase in the transparency and traceability of the EU agri-food economy likely generates additional benefits to EU consumers and producers. Some portion of the losses to international exporting countries may be offset due to increases in purchases (and prices) for domestic suppliers. As a result of the fraud, consumers may also be forced to pay higher prices or be deprived of access to certain food products. Reduction in the incidence of fraud may also alter the consumer utility calculus with respect to consumption of certain food products or categories. Our analysis does not account for these effects and cannot separate trade effects due to a reduction in total demand versus substitution towards domestic sources.

Limitations notwithstanding, the results are—at least in some sense—a ringing endorsement for food safety information networks like the RASFF. When such networks are used, the benefits of fraud identification extend beyond the removal of the non-compliant product. Our findings indicate that the publicity generated by RASFF fraud alert information is a motivator for long-term behavior change. Retailer adaptation can ensure food products are safe and quality assured in the future. Many European retailers, for example, now use private food safety standards, such as GLOBALG.A.P. and BRC Global, that enable international suppliers to assure the quality of their products through third-party certification schemes. Exporting countries can facilitate this process through the adoption of local voluntary standards certification schemes that function as a stepping stone to GLOBALG.A.P. or BRC Global compliance.

References

Ali Meerza, Syed Imran, and Christopher R. Gustafson. 2018. "Consumer Response to Food Fraud." *Selected paper for 2018 Agricultural & Applied Economics Association Annual Meeting.*

Ali Meerza, Syed Imran, Konstantinos Giannakas, and Amalia Yiannaka. 2018. "Optimal Policy Response to Food fraud." *Selected Paper for 2018 Agricultural & Applied Economics Association Annual Meetings.*

Barnett, Julie, Fiona Begen, Sophie Howes, Aine Regan, Aine McConnon, Afrodita Marcu, Susan Rowntree, and Wim Verbeke. 2016. "Consumers' confidence, reflections and response strategies following the horsemeat incident." *Food Control*, 59: 721–730.

Baylis, Kathy, Andrea Martens, and Lia Nogueira. 2009. "What drives import refusals?" *American Journal of Agricultural Economics*, 91(5): 1477–1483.

Baylis, Kathy, Lia Nogueira, and Kathryn Pace. 2010. "Food import refusals: Evidence from the European Union." *American Journal of Agricultural Economics*, 93(2): 566–572.

BBC News. 27 February 2013. "Tesco pledges to sell meat from "closer to home"." *BBC News,* available at https://www.bbc.com/news/uk-21597596.

Bellemare, Marc F, Takaaki Masaki, and Thomas B Pepinsky. 2017. "Lagged explanatory variables and the estimation of causal effect." *The Journal of Politics*, 79(3): 949–963.

Butler, Sarah, and Rebecca Smithers. 2014. "Horsemeat scandal results in slide in sales of red meat in Britain." *The Guardian.*

Jouanjean, Marie-Agnès, Jean-Christophe Maur, and Ben Shepherd. 2015. "Reputation matters: Spillover effects for developing countries in the enforcement of US food safety measures." *Food Policy*, 55: 81–91.

Kowalska, Aleksandra, Jan Mei Soon, and Louise Manning. 2018. "A study on adulteration in cereals and bakery products from Poland including a review of definitions." *Food Control*, 92: 348–356.

Manning, Louise, and Jan Mei Soon. 2014. "Developing systems to control food adulteration." *Food Policy*, 49: 23–32.

Manning, Louise, Robert Smith, and Jan Mei Soon. 2016. "Developing an organizational typology of criminals in the meat supply chain." *Food Policy*, 59: 44–54.

McElwee, Gerard, Robert Smith, and John Lever. 2017. "Illegal activity in the UK halal (sheep) supply chain: Towards greater understanding." *Food Policy*, 69: 166–175.

Moyer, Douglas C, Jonathan W DeVries, and John Spink. 2017. "The economics of a food fraud incident–Case studies and examples including Melamine in Wheat Gluten." *Food Control*, 71: 358–364.

Red Tractor. 2018. "Licensees." *Red Tractor website*, available at www.redtractor.org.uk.

Silva, JMC Santos, and Silvana Tenreyro. 2006. "The log of gravity." *The Review of Economics and statistics*, 88(4): 641–658.

Smith, Robert, Louise Manning, and Gerard McElwee. 2017. "Critiquing the inter-disciplinary literature on food fraud." *International Journal of Rural Criminology*, 3(2): 250–270.

Smith, Rob, Gerard McElwee, and Peter Somerville. 2017. "Illegal diversification strategies in the farming community from a UK perspective." *Journal of Rural Studies*, 53: 122–131.

Somerville, Peter, Robert Smith, and Gerard McElwee. 2015. "The dark side of the rural idyll: Stories of illegal/illicit economic activity in the UK countryside." *Journal of rural studies*, 39: 219–228.

Song, Cen, and Jun Zhuang. 2017. "Modeling a government-manufacturer-farmer game for food supply chain risk management." *Food Control*, 78: 443–455.

Spink, John. 2012. "Improving Import Food Safety." , ed. Wayne Ellefson, Lorna Zach and Darryl Sullivan, Chapter Defining Food Fraud and the Chemistry of The Crime, 195–216. Wiley Online Library.

Spink, John, and Douglas C. Moyer. 2011. "Defining the public health threat of food fraud." *Journal of Food Science*, 76(9).

Spink, John, and Douglas C Moyer. 2013. "Understanding and combating food fraud." *Food Technology*, 67(1).

Spink, John, Neal D Fortin, Douglas C Moyer, Hong Miao, and Yongning Wu. 2016. "Food fraud prevention: Policy, strategy, and decision-making–implementation steps for a government agency or industry." *CHIMIA International Journal for Chemistry*, 70(5): 320–328.

Telegraph. 2013. "Horse meat scandal: timeline." *Telegraph*.

United Nations Statistics Division. n.d.. "UN Comtrade Database."

Yamoah, Fred Amofa, and David Eshun Yawson. 2014. "Assessing supermarket food shopper reaction to horsemeat scandal in the UK." *International Review of Management and Marketing*, 4(2): 98.