Consumers' Costly Responses to Product-Harm Crises*

Rosa Ferrer † Helena Perrone ‡

June 2017

Abstract

Using an ideal setting from a major food safety crisis, we estimate a full demand model for the unsafe product and its substitutes and recover consumers' preference parameters. Counterfactual exercises quantify the relevance of different mechanisms –changes in safety perceptions, idiosyncratic tastes, nutritional characteristics, and prices–driving consumers' response. We find that consumers' reaction is limited by their taste for the product and its nutritional characteristics. Due to the costs associated with switching away from the affected product, the decline in demand following a product-harm crisis tends to understate the true weight of such events in consumers' utility. Indeed, we find that a large fraction of consumers are unresponsive to the crisis even when they significantly downgrade their product safety perception. For an accurate assessment of the crisis, managerial strategies should therefore account for how different demand drivers bind consumers' substitution patterns.

Keywords: Food safety, demand estimation, scanner data, idiosyncratic utility parameters, nutritional preferences

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*Research support from INRA, the Spanish Commission of Science and Technology (ECO2010-15052, ECO2008-01116, and ECO2013-43011-P) and the Government of Catalonia is gratefully acknowledged.

†Universitat Pompeu Fabra and Barcelona GSE, rosa.ferrer@upf.edu.

‡Universitat Pompeu Fabra and Barcelona GSE, helena.perrone@upf.edu

1 Introduction

Product-harm crises are frequent and affect a wide variety of industries, such as automobiles, mobile phones, and food.[1] The consumer backlash that usually follows these crises can have severe consequences for firms' revenues, increasing firms' incentives to invest in monitoring the production process and to comply with best-practice charts.[2] However, this self-disciplining mechanism is weakened if a lack of good substitutes for the affected product constrains consumer responses. A better understanding of these constraints is fundamental for the assessment and management of such crises.

In this paper, we provide a framework to study and quantify the tradeoffs that consumers face in responding to product-harm crises. These tradeoffs are particularly sharp when brands cannot prevent negative spillovers to other firms (Freedman et al. (2012)), such that consumers substitute to other product categories instead of switching sellers or manufacturers. Crisis response can therefore be especially costly for consumers if they have to switch to categories with characteristics that differ substantially from their initial choice. Whereas previous literature has made relevant contributions by studying the impact of product-harm crises on brands (see, in particular, Liu and Shankar (2015) and Zhao et al. (2011)), this paper focuses on how preferences bind responses to product-harm crises which affect a large share of firms in an industry.[3]

Exploiting an exogenous change in the safety of an important food category in consumers' consumption basket, this is the first paper to recover consumers' product safety preferences. We estimate a full demand model and recover the utility parameters governing the extent to which consumers care about safety, prices, nutritional characteristics, and taste. Counterfactual exercises isolate the roles played by each of these dimensions in consumers' demand reaction to the safety crisis. Another distinguishing characteristic of our work is that we study consumers' reactions to safety crises without having to rely on product recalls as the event igniting the crisis. In our case, and as explained in detail below, we rely on an unanticipated and exogenous event, unrelated to potentially endogenous firm decisions.

[1] For instance, in the automobile industry, hundreds of deaths were caused by faulty ignition devices in General Motors' cars and unintended acceleration problems in Toyota cars (please see Fortune, August 24, 2015, "Ten times more deaths linked to faulty switch than GM first reported", and The Economist, February 11, 2010 "Accelerating into trouble"). In the mobile phone industry, there was a product recall of nearly 2 million Samsung Galaxy Note 7 smart phones sold before September 2016 due to fire and explosion cases, US Consumer Product Safety Commission (2016)). In the area of food safety, in recent decades, there have been frequent safety crises with diverse origins, such as microorganisms (e.g., E. coli in spinach, salmonella in peanut butter), toxic substances (e.g., melamine in pet food, mercury in fish, arsenic in chicken and rice, high lead concentrations in children's toys), and potentially fraudulent practices (e.g., the 2013 horse meat scandal). For further information, see www.fda.gov/food and www.efsa.europa.eu.

[2] For instance, in consumer surveys, a majority of consumers report having avoided the purchase of certain brands or food categories as a direct result of new safety information released by public authorities or product recalls, The Gallup Poll on Consumption Habits, 2007 and 2008.

[3] Among many others, see, for example, two recent prominent cases, the 2007 toy-recall crisis and the 2013 horse meat scandal. In the 2007 toy-recall crisis, both investors and consumers seemingly interpreted the toy recalls as resulting from widespread unsafe practices in the sector (Freedman et al. (2012)). The 2013 horse meat scandal also affected a wide range of retailers and manufacturers that used common outsourcing networks, thereby affecting the credibility of existing practices regarding the monitoring of providers. More generally, outsourcing, which is frequently an industry-wide practice, has been associated with greater incidence of product-harm crises, Flynn and Zhao (2014).

Our results show that consumers' reactions to a safety crisis are heterogeneous and limited by how much they like the affected product. Comparing consumers who care equally about safety and make the same update to their safety perception after the crisis, we find that those with a high estimated taste for the unsafe product are inelastic to safety shocks, whereas consumers who like the product less are highly responsive to changes in perceived safety. The results also show that consumers' reaction to the crisis would be stronger if alternative products with comparable characteristics were available. These results have at least two potential implications for product-harm crisis management: first, consumers' response should be interpreted while accounting for how costly it is for consumers to adjust their consumption; second, in the medium to long run, the entry of new products with comparable characteristics could revive the demand reaction to the crisis.

Our empirical application focuses on the mad cow epidemic and exploits the timing of an abrupt and unanticipated safety scare event in the fall of 2000 in France. The crisis originated domestically when French beef infected with mad cow disease appeared on the shelves of major national distribution chains. Widely publicized in the media, the event cast doubt on the effectiveness of the regulatory policies and monitoring procedures, in particular, of grocery stores.[4]

We estimate preference parameters in a demand model based on Dubois, Griffith, and Nevo (2014), which we extend to analyze product-harm crises. The consumer's utility depends not only on product quantities and nutritional characteristics but also on unobservable tastes and safety perceptions. Although safety is unobservable, we can estimate the change in safety perception following the fall 2000 event. We estimate the demand for different meat products, including fish. The estimable equation is aggregated at the meat category level, but the product nutritional content is measured at the most disaggregated level of consumer choice (for example, the nutritional content of 1 gram of ribeye steak, 1 gram of pork tenderloin, or 1 gram of chicken breast). Perceived product safety is modeled as an unobservable product characteristic.

Variation in perceived product safety can be identified separately from other unobservable shocks under the assumption that safety perceptions before the mad cow disease event were constant over time. The unobserved taste for the category is household specific and consists of the utility that consumers derive from a product that cannot be explained by the product's nutritional characteristics or by the shock to the perceived safety level.

Note that the demand model that we use is better suited to the empirical exercise at hand than discrete choice models or almost-ideal demand system models (AIDS, Deaton and Muellbauer (1980)). Discrete choice models (e.g., random utility models, Berry (1994) and Berry et al. (2004)) are appropriate for studying substitution across differentiated products within a category but less suitable for comparisons across categories. Furthermore, when examining pur-

[4]An initial mad cow scare had occurred four years earlier, in March 1996, which was triggered by the outbreak in the UK. Both crises had large impacts on consumption (INSEE (2007)); however, the second crisis was unanticipated and domestic, making it more suitable for our exercise. Because the first crisis originated in the UK, it was rapidly controlled in France by banning imports of British beef products. Additionally, the first crisis did not have an exact start date. The available information on mad cow disease from various sources was contradictory until, in March 1996, the UK government fully disclosed the risks associated with beef consumption.

chase data across categories, we frequently observe multiple purchase choices during the same period, another feature for which the discrete choice framework is less suitable. AIDS and other models in the product space are not better alternatives because they do not allow for the study of the effects of different product characteristics (other than prices) on consumers' choices.

The empirical exercise uses a comprehensive, individual-level scanner data set that includes every food product purchased by a large sample of French households over 5 years, from 1999 to 2003. The data include product and store characteristics, as well as household demographics. This data set is complemented by information on the nutritional characteristics of highly disaggregated meat products (in general, the data are provided at the level of the meat cut). We consider 6 product categories: beef and veal, beef and veal offal (hereafter, offal), poultry, pork, fish, and other meats (e.g., lamb, horse, game). We focus on three nutrients: proteins, lipids and iron. The nutritional content data are drawn from the French Observatory of Food Nutritional Quality (CIQUAL). We also collected the frequency of news stories on mad cow disease from the French press, which we use to control for the intensity of the product-harm crisis.

The estimation results show a significant decline in the perceived safety of beef, veal and offal in the three months after the event. In addition, they indicate that nutritional composition is a significant determinant of consumers' meat choices.[5] In particular, the coefficient for iron, which is an essential nutrient for the general population, and especially for children and pregnant women, is positive and significant. As we show, beef has the highest iron content, and the demand reaction to the safety crisis leads to a decrease in iron consumed from animal sources.[6]

We then perform a first counterfactual exercise that isolates the effect of changes in consumers' safety perceptions following the event (maintaining price as before the shock). Purchased quantities of beef and veal are 9% higher, on average, due to the update in consumer beliefs regarding product safety. We show that to produce an equivalent demand reaction, the prices of beef and veal would have had to increase by nearly 20%.

In the second counterfactual exercise, we compare observed quantities to simulated quantities in a counterfactual scenario in which consumers' estimated taste for the affected product category is the same as the estimated taste for one of the least favorite categories. The estimates of the unobserved taste for different categories indicate that beef and veal is the average consumer's favorite category, while offal and pork are the least favorite categories. The analysis shows that if the average consumer's taste for beef and veal were the same as his taste for pork, the average decrease in the demand for beef and veal after the safety event would have been 25% higher. In addition to the average response, we study individual responses to the safety

[5]Even if most consumers do not know products' exact nutritional values, they may know basic nutritional facts (e.g., beef has more iron than chicken) and choose products accordingly. Moreover, there is evidence that hunger and appetite are associated with nutritional needs (Hill and Blundell (1986); Barkeling et al. (1990)).

[6]Although iron can be obtained from other types of food, iron from animal sources has a substantially higher absorption rate (Alexander et al. (1994)). A sudden dietary change is especially relevant because the incidence of iron deficiency in some populations can be large, even in developed countries with low incidences of undernourishment. For example, Black et al. (2013) reports that the incidence of iron-deficiency anemia in Europe is approximately 12% in children and 16% in pregnant women.

shock. Individual responses are heterogeneous, with consumers who have a stronger taste for beef and veal reacting notably less than consumers who have a weaker taste for the affected category.

In the third counterfactual exercise, we measure the relevance of nutritional composition in explaining consumers' reaction to the crisis. We compare observed quantities after the crisis with simulated quantities if beef and veal had, on average, the same nutritional composition as poultry, the average consumer's favorite meat category. We find that the demand would have declined 19% further if poultry and beef (or veal) had similar nutritional characteristics.

Finally, the last counterfactual quantifies what part of the demand reaction was due solely to change in relative prices (maintaining the safety level as before the crisis). We show that relative prices were only a minor driver of consumers' reaction if compared to the relevance of tastes, nutritional availability, and safety updating in explaining demand responses.

The paper is organized as follows. In the rest of this section, we review the empirical literature on product-harm crises, with a particular emphasis on food scares and the mad cow disease crisis. We also discuss our contribution to the existing literature in greater detail. Section 2 describes the mad cow disease epidemic in France, summarizing the main events that affected public opinion on this matter. Section 3 describes the model, and Section 4 reports the data and descriptive statistics. Section 5 describes the econometric approach. Section 6 reports the results of the demand estimation and the counterfactual exercises. Section 7 considers an alternative demand specification using the number of newspaper articles about the event as a continuous measure of (perceived) product safety. Section 8 studies the effects of the crisis on the characteristics composition of consumers' basket. The last section discusses the results and their managerial implications and concludes.

Comparison to the literature

There is an extensive literature on product-harm crises in both Economics and Marketing. A large part of this literature relies on reduced-form exercises to study how product safety crises impact sales, firm revenues, and market shares. Examples are Hartman (1987), Marsh et al. (2004), Ma et al. (2010), Freedman et al. (2012), and Borah and Tellis (2016). There is also a branch of the literature that studies how consumers react to product-harm crises in lab experiments (Siomkos and Kurzbard (1994), Lei et al. (2012), Ahluwalia et al. (2000)).

In contrast to this previous body of literature, we employ a structural demand approach that allows us to recover preference parameters over product characteristics and to conduct counterfactual exercises. We are able not only to quantify the observed demand decrease but also to study the importance of different mechanisms driving consumers' responses (prices and other observable and unobservable product characteristics).

Relevant papers that also follow a structural demand approach are Liu and Shankar (2015) and Zhao et al. (2011). Liu and Shankar (2015) examine various product recalls in the US automobile industry. They study how the effect of the recalls on brand preference depends on recall characteristics such as media attention, recall severity, and expected quality of the recalled product. The paper studies both short- and long-run effects by allowing recalls to affect brand preferences over time. Their results show that consumers' negative response to recalls increases with media attention and the severity of the product defect that triggered the recall (for example, whether the defect could be fatal).

Zhao et al. (2011) model consumer choices when there is uncertainty over product quality and consumers learn about mean product quality through own experience and product recalls. Focusing on a peanut butter safety crisis in Australia, they investigate how the crisis affected consumers' sensitivities to price, quality and risk by allowing demand model coefficients to vary with period (before, during and after the crisis). They find that the price coefficient is closer to zero during the crisis than before or after it.

Our paper differs from and complements the two above-mentioned papers by focusing on the analysis of crises with industry-wide effects, instead of brand-specific effects. To do so, we use a continuous choice demand model instead of a discrete choice model. A continuous choice model allows consumers to react both on the intensive and the extensive margins, i.e., by not only switching away from the affected product but also adjusting the quantities purchased conditional on product choice. When the crisis is industry wide, there is only a small fraction of consumers willing to incur the costs of completely avoiding the whole product category (instead of just switching brands within a category). Therefore, the continuous choice framework provides a broader picture of consumer responses to industry-wide crises, as it permits us to consider consumers' responses on both margins.

Although our application focuses on a specific product-harm crisis, we believe that our analysis is informative of consumers' responses to product-harm crises in general. The crisis that we examine received substantial media attention, thus making the fraction of uninformed consumers close to negligible. Therefore, we can study frictions in consumers' responses that are not due to a lack of information.[7] Furthermore, we have a clearly exogenous and unanticipated shock that triggered the crisis, whereas many product-harm crises, when triggered by a decision of the firm as is the case in many product recalls, could arguably be endogenous.

Note that our model also includes dynamic effects, allowing for the study of the long-term effects of a product-harm crisis on consumers' preferences and choices. However, we are careful in interpreting these effects because they could be capturing unobserved shocks other than the long-run effect of the crisis (for example, changes in regulation, government announcements, the arrival of new information on the epidemic, etc.)

In our model, crises do not affect price coefficients (or coefficients in general). Instead, we treat product safety as an unobservable characteristic of the product and are able to estimate the change in this characteristic following a major product safety event without having to assume a parametric specification. Note that safety in our model could also be broadly interpreted as product quality, depending on the application.

Prominent papers that also examine the mad cow epidemic are Schlenker and Villas-Boas (2009) and Adda (2007). Schlenker and Villas-Boas (2009) study how sales and future cattle

[7] Therefore, our paper complements the literature on the effects of increased information on consumers' and firms' behavior (e.g., Jin and Leslie (2003)). Our findings show that even when consumers are aware of potential risks, substituting away from their initially optimal purchase choices can be costly.

prices respond to two different events related to mad cow. The first event took place in April 1996, when mad cow disease was discussed on a popular American TV talk show (Oprah). The second was in December 2003, when a cow was diagnosed with mad cow for the first time in the US. They find that the negative effects of the talk show were considerably larger but more short-lived than the effects of the first diagnosis.

Adda (2007) studies how previous exposure to risky products might influence consumption once the risk is made public. Adda (2007)'s results show a non-monotonic purchase response as a function of previous exposure to the risky product, and consumers with intermediate levels of previous exposure exhibited the strongest reactions. The effect of previous exposure on the consumer response is estimated as an interaction effect between past consumption and the information shock. This dynamic perspective requires one to abstract from the potential role of (static) households' unobserved taste for the product. In particular, Adda (2007) uses a model in differences that focuses on changes within individual behavior, canceling out individual preference fixed effects. Using a different approach, our analysis recovers household utility parameters and examines their role in explaining consumers' heterogeneous responses. We believe that it is crucial to investigate the role of unobserved preferences because they are determinants of past consumption and of the response to the information shock.

Our analysis may be of interest to the literature on consumers' behavioral biases.[8] We use a model of utility-maximizing consumers conditional on consumers' perceptions. Thus, consumers' perceptions could still be subject to non-rational biases. In particular, product-harm crises could be related to the literature on salience (Bordalo et al. (2012), Bordalo et al. (2013)) due to their potential extreme shocks to health relative to the average health risks that consumers face.

Finally, our paper also contributes to a law and economics debate about the role of market forces in the production of safe products (in particular, Polinsky and Shavell (2010), Goldberg and Zipursky (2010), Ganuza et al. (2016), Daughety and Reinganum (2012), and Choi and Spier (2014)) by showing empirically that consumers' market's response is constrained in the absence of close substitutes for the affected product.

2 The mad cow epidemic in France

Bovine spongiform encephalopathy (BSE), commonly known as mad cow disease, originated from the use of meat-and-bone cattle feed. The beef industry had widely adopted this form of animal-based feed as an alternative protein source to, for example, soybean feed. UK authorities banned its use in 1988, once the link to the BSE had been established. However, the ban was not perfectly enforced, in part due to the lack of incentives to report and to imperfect surveillance systems. France banned animal-based feed later on, in 1990, and in 1994, reinforced the ban and its control (Al-Zoughool et al. (2010)).

[8] For instance, Chambers and Melkonyan (2013) provide a behavioral model of uncertainty perception to argue that the sharp drops in consumption following product-harm crises could be due to ambiguous beliefs.

Authorities initially excluded the possibility of BSE transmission to humans. In 1993, following the death of a British dairy farmer, researchers found links between the BSE and Creutzfeldt-Jakob disease (vCJD), the human variant of BSE (Sawcer et al., 1993; Smith et al., 1995). However, it was unclear whether the transmission resulted from consumption of infected beef or direct contact with infected animals. In 1994 and 1995, new cases affecting non-farmers reinforced the hypothesis of transmission via beef consumption. However, it was not until March 20, 1996, that the British Secretary of State for Health, Stephen Dorrell, officially confirmed the likely link between the deaths of several UK citizens and BSE. As a consequence, British beef was banned in France from March 1996 until October 2002 (Borraz et al. (2006)).[9]

In this paper, we focus on the second French crisis, which began in October 2000. Unlike the first one, the origin of the second crisis was of domestic origin. Three large supermarket chains (Auchan, Carrefour and Cora) sold meat that was subsequently found to be infected with BSE.[10] The three supermarket chains had purchased the beef from a meat producer in Normandy. There were three major reasons for consumers' concerns during this second crisis: first, there was evidence that the ban on meat-and-bone meal imposed in 1990 had not been fully enforced; second, unlike in the UK, high-risk cattle (i.e., cattle over the age of 30 months, as the long incubation period of the disease made younger cows less dangerous for human consumption) were not banned for human consumption until January 2001; third, the number of French cows detected to be infected with BSE had increased from 31 in 1999 to 161 in 2000 (Al-Zoughool et al. (2010)).

Figure 1 shows the number of French newspaper articles mentioning the words "meat" and "mad cow" from December 1999 to December 2001. As is common in product safety scares, there was a sharp rise in the number of articles immediately after the infected meat was found in October 2000. This sharp rise is additional evidence that the event was unexpected.

Overall, the mad cow disease epidemic caused the deaths of more than 200 persons worldwide. After the UK, France was the country with the largest number of human victims (26 deaths).[11] Producers were not held legally liable because their products conformed to the safety regulations in place before the mad cow scare, as European Union legislation excluded the primary sector from the strict liability regime that applied to product safety. Thus, vCJD victims were compensated by governments rather than by producers. Due to the mad cow scare, the legislation was revised to include agricultural products in the strict liability regime.[12]

The second French mad cow crisis provides an ideal setting to study consumer responses to unanticipated informational shocks. First, as the shock was unexpected, consumers were unable to anticipate or dissipate their response. Second, given the widespread media coverage, the fraction of uniformed consumers was likely very small. Third, unlike the case of toys or other food products, there is a well-defined set of substitutes for the affected product, namely

[9] In 1999, the European Union lifted the ban on British beef, but France decided to maintain its ban, causing a legal and political dispute between the two countries.

[10] BBC, October 21, 2000, "Suspect beef triggers French BSE scare;" BBC, October 27, 2000, "More suspect beef sold in France."

[11] UK National CJD Research & Surveillance Unit

[12] Council Directive 85/374/EEC, amended by Directive 1999/34/EC.

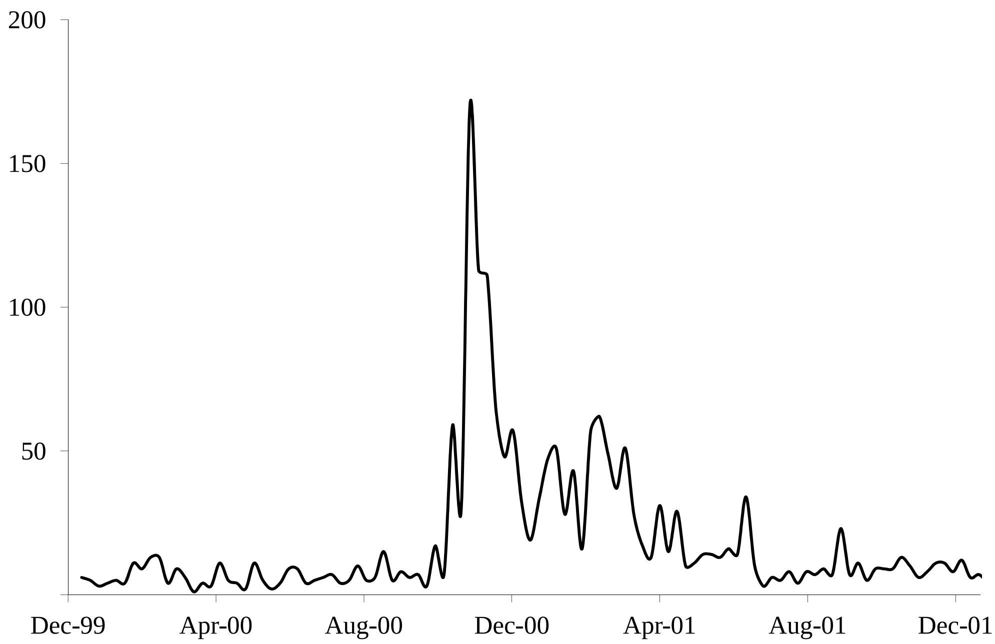

Figure 1: Source: Lexis-Nexis. Weekly number of newspaper articles in the French written press mentioning the words "viande" (meat) and "vache folle" (mad cow), 2000-2001.

other fresh meat, including fish.

3 Data and descriptive statistics

Information on purchase choices and characteristics come from a French nationally representative household-level scanner data set, which covers the period 1999-2003. Households in the sample are given a scanner to record all food purchases during the period. We focus on the subsample of households that buy fresh meat products, including fresh fish. This subsample consists of 3618 households. For each product purchased by the household, there is information on the quantity, price, date of the purchase, and the retailer where it was purchased. There is also comprehensive information on household demographics.

We merge the purchase data with meat-cut-level nutritional information we collected from the French Observatory of Food Nutritional Quality (CIQUAL). In a minority of cases in which nutritional information from CIQUAL was not available for a given meat cut, we used nutritional information from CIV-INRA.[13] The two relevant macronutrients present in meat are proteins (g per 100g) and lipids (g per 100g), as fresh meat and fish contain no carbohydrates.[14] We

[13]Analyses des Compositions Nutritionelles des Viandes, CIV-INRA, 2006-2009, http://www.lessentielesviandes-pro.org.

[14]Calories are generally calculated as a weighted sum of the main nutritional components. The weights used by CIQUAL are 4 kcal/g for proteins and 9 kcal/g for lipids. Other main components of caloric content such as

also consider iron (mg per 100g) because it is a key micronutrient present in meat, as noted in the literature on clinical nutrition (Alexander et al. (1994)).[15]

We also use Lexis-Nexis data on news stories published in the French written press that mention “mad cow” and “meat”. Figure 1 shows how the number of mad cow news stories per month varies over time.

We study purchases of fresh meat and fish, classified into six categories: beef and veal (in some of the tables, we present summary and descriptive statistics for beef and veal separately), offal, poultry, pork, other meat, and fish. The category “other meat” includes lamb, rabbit, horse and more rarely consumed meats such as ostrich, wild boar, and roe deer.

Table 1 reports the category average quantity purchased in a month per household, the average category price conditional on purchases, and the average number of households that purchase each category in a given month. It also reports, in the last column, the average monthly volume market share of each product category. Conditional on purchases, poultry is the most consumed category (2.12 kg per month on average), followed by beef and veal (including offal), while the least consumed category is offal, followed by other meat. Beef and veal is the most expensive category, followed by other meat and fish. In terms of number of households who purchase the category, beef and veal is the category with the highest number of households purchasing each month (more than 2000 households, if we include purchases of offal). A large group of households also purchase poultry (more than 1500 on average each month). The categories consumed by the lowest number of households are offal and other meat. They also have the lowest market shares. In terms of market shares, beef and veal are the most important category, followed closely by poultry.

Table 2 presents the average nutritional composition of each product category and the resulting average price of each nutritional component, which is constructed as the ratio between the average category price conditional on purchases and the average category nutritional content. In this table, we report summary statistics separately for beef and veal due to the differences in nutritional content (especially iron) between the two. Beef and offal are the categories with the highest iron content. The difference in iron content can be quite large: compared to poultry, for example, the iron content in beef and offal is more than twice as large. Although, as shown in Table 1, offal and beef are among the most expensive categories, due to their high iron concentration, they are among the cheapest sources of iron (0.20 euros/mg and 0.38 euros/mg respectively), alongside pork (0.36 euros/mg). Note that pork is also the cheapest source of lipids and proteins.

3.1 Market shares and prices

Table 3 reports the effect of the mad cow event on the average price of beef and veal, poultry and pork using both a variable- and a fixed-weight price index (first and second columns), as

carbohydrates and alcohol are not relevant in our case because they are not present in fresh meat or fish.

[15]Iron in red meat, poultry and fish usually constitutes only approximately 10% of the total iron intake in European omnivore diets, but the absorption of iron from animal proteins is approximately 5 times larger than the absorption of iron from plant sources, Hercberg et al. (2001) and Alexander et al. (1994).

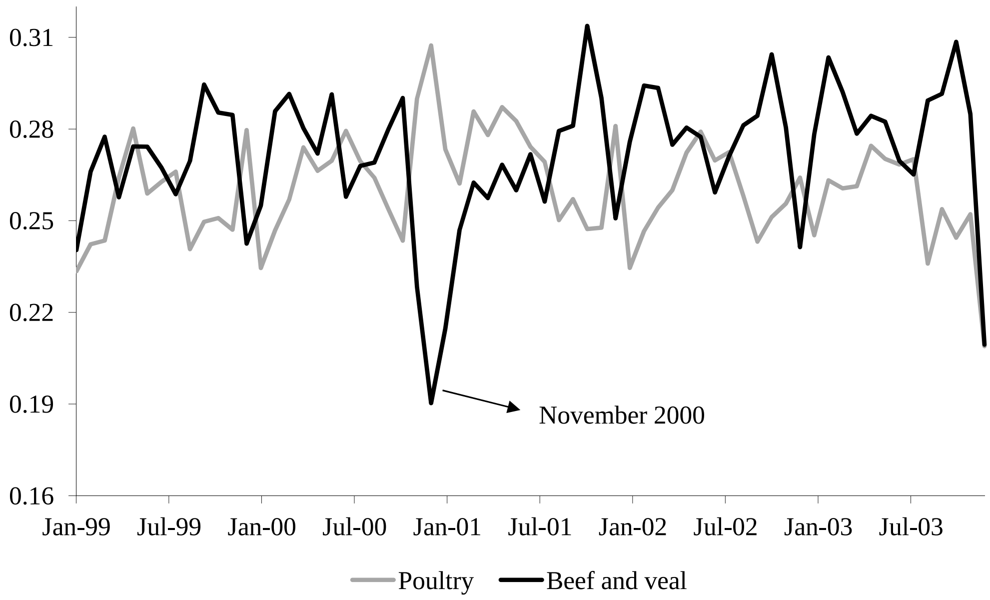

Figure 2: Monthly market shares, 1999-2003

well as on the volume market shares of each of these categories.

Regarding the changes in market shares, we observe a significant decline in the beef and veal market share in the 3 months following October 2000. During this period, demand appears to have shifted from beef to poultry, as suggested by the positive and significant coefficients of the interaction of 1 to 3 months after the event and the poultry market share (Column 3 of Table 3). In contrast, the events had no apparent significant effect on the market share of pork (Column 3 of Table 3) or on other types of fresh meat and fish. In fact, most of the demand appears to have shifted from cow meat to poultry, as illustrated in Figure 2, even though their nutritional characteristics differ considerably. Therefore, households' unobserved taste for the different categories appears to have played a key role in the substitution pattern.

We investigate the change in prices following the October 2000 event by calculating two different price indexes: a variable-weight price index and a fixed-weight price index. The variable price index weights product (meat cuts) prices by the volume market share of the product in each period. Therefore, the index measures changes in transaction prices combined with potential demand shifts toward more or less expensive products within a meat category. In contrast, a fixed price index weights product prices by the average (across all periods) product volume market share, and hence, the weight of each product is the same throughout the period. Thus, by maintaining fixed the weight of each product, the fixed price index separates transaction prices from demand movements. We consider both indexes to capture potential demand shifts within categories after the safety shock.

To see more clearly how these indexes differ, suppose for example that the variable price index remains constant. This could indicate that transaction prices and demand have not changed, but it could also be that transaction prices have gone down and demand has shifted to more expensive products (or that transaction prices have gone up and demand has shifted to less expensive products) such that the net effect on average prices conditional on purchases is zero. We would need to look at the fixed price index to distinguish between these possible price and demand shifting effects. If the fixed price index also remains constant, this would indicate that there is no evidence that transaction prices have changed.

This example describes what we observe in Table 3. The coefficient of the interaction of the category dummies with the dummies indicating 1 to 10 months after October 2000 are non-significant for all products and for neither of the two price indexes, suggesting that the events had little impact on prices. This is consistent with the agricultural statistical reports at the time (INSEE (2007)), which relate that although intermediate prices varied during the crisis, the same was not true for consumer prices.

4 The model

4.1 The setup

Our demand model is based on Dubois et al. (2014)'s approach. Consumers' utility depends on quantity consumed and product characteristics.

Household i chooses quantities of the N food products (plus the numeraire) to maximize utility subject to the budget constraint. The N products are divided into J product categories, each group j having K_j subcategories. A product is labeled kj if it is the kth item of category j, where $k \in \{1, 2, ..., K_j\}$. We consider the following utility function:

$$U(x_i, z_i, y_i; \eta_i) = \prod_{j=1}^{J} \left(\sum_{k=1}^{K_j} f_{ikj}(y_{ikj}) \right)^{\mu_{ij}} \prod_{c=1}^{C} h_{ic}(z_{ic}) exp(\gamma_i x_i) \tag{1}$$

where z_i is the vector of product characteristics, y_i is the vector of quantities of food products purchased, x_i is the quantity of the numeraire, and η_i are socio-demographic characteristics of household i. Each product n has C characteristics $\{a_{n1}, ..., a_{nC}\}$. Let $C\ X\ 1$ be the dimension of the vector of characteristics, z_i. Then, $z_i = A' y_i$, where the matrix $A \equiv \{a_{nc}\}_{n=1,...,N; c=1,...,C}$, measures product characteristics per unit of consumption.

The utility function is weakly separable across the J groups, but utility from products in different categories interact through their characteristics, z_{ic}. The utility obtained from products within the same group and from product characteristics are given by the individual-specific utility functions f_{ikj} and h_{ic}, respectively. As in Dubois et al. (2014), we assume that the utility for products within a given category is described by a CES utility function $f_{ikj}(y_{ikj}) = \lambda_{ikj} y_{ikj}^{\theta_{ij}}$, where the elasticity of substitution for a group category j is given by $1/(1 - \theta_{ij})$. With respect to product characteristics, we assume that $h_{ic} = e^{\beta_c z_{ic}}$, which implies that the utility for product groups and product characteristics is Cobb-Douglas.

The model is very flexible with respect to consumer and product heterogeneity. The specific functional forms we use, however, impose some constraints on how income and prices affect demand. In particular, expenditures in each food group will depend on individual consumer characteristics, but quantity will not vary with changes in consumer income —though note that in the estimation we can control for income variation across consumers. Additionally, the model limits non-linear price effects.

4.2 Household behavior

Using the utility function specifications mentioned above, the problem of the household is to maximize utility by choosing the quantity of the numeraire, x_i, and the quantity of food, y_i, subject to a budget constraint:

$$\max_{x_i,y_i} \prod_{j=1}^{J} \left(\sum_{k=1}^{K_j} \lambda_{ikj} y_{ikj}^{\theta_{ij}} \right)^{\mu_{ij}} \prod_{c=1}^{C} exp(\beta_c z_{ic} + \gamma_i x_i)$$
$$s.t. \sum_{k=1}^{K_j} y_{ikj} p_{kj} + p_0 x_i \leqslant I_i$$
$$z_i = Z' y_i$$
$$x_i, y_i \geqslant 0$$

where p_{kj} is the unit price of food, p_0 is the price of the numeraire, and I_i is household i's income.

Hence, the first-order condition of the household' maximization problem is given by:[16]

$$\sum_k p_{ik_j} y_{ij} = p_0 \frac{\mu_{ij}\theta_{ij}}{\gamma_i} + \sum_c p_0 \frac{\beta_c}{\gamma_i} \sum_k a_{kjc} y_{ikj} \tag{2}$$

Note that the first-order condition is aggregated at the food-group level. Indeed, the left-hand side variable is the household's expenditure on food group k_j. The household's estimable purchase decision equation derives from the first-order condition above. In the next section, we explain how to apply it to the data.

5 Econometric Implementation

5.1 The estimable equation

The estimable equation comes from the first-order condition of the consumer problem (equation 2). We include a time subscript, t. Assuming that one of the characteristics ($c = 1$) is unobserved, we let $p_0 \frac{\mu_{ij}\theta_{ij}}{\gamma_i} + p_0 \frac{\beta_1}{\gamma_i} \sum_k a_{kj,1} y_{ikj} = \sum_{t=\tau}^{T} \mathbb{1}_{j=b} \psi_t + \delta_{ij} + \xi_t + \epsilon_{ijt}$. Including an unobservable characteristic that measures changes in product safety perception is a novelty of our work and which is not considered in Dubois et al. (2014). The change in consumers' safety perception is measured by $\sum_{t=\tau}^{T} \mathbb{1}_{j=b} \psi_{it}$, where $t = \tau$ denotes the period of the event that triggers

[16] See Dubois et al. (2014) for details on the derivation.

the safety crisis and $\mathbb{1}_{j=b}$ is an indicator function equal to 1 if the product category is affected by the safety crisis (beef, veal, and offal) and zero otherwise. Thus, $\psi_{i,t\geq\tau}$ measures the per period variation in the safety perception of consumers. Apart from the safety component of the unobservable characteristics, the household-category effect, δ_{ij}, captures the household-specific preferences for the meat category that cannot be explained by the nutritional characteristics and by the safety shock (flavor, for example). In addition, the period fixed effects, ξ_t, control for temporal or seasonal shocks to meat demand that are common to all meat categories, whereas ϵ_{ijt} captures interactions between the previous effects (household-category-specific shocks that vary over time).

Thus, the estimable equation is:

$$\omega_{ijt} = \sum_{c=2}^{C} \beta_c z_{ijct} + \sum_{t=\tau}^{T} \mathbb{1}_{j=b}\psi_t + \delta_{ij} + \xi_t + \epsilon_{ijt}, \tag{3}$$

where $\omega_{ijt} = \sum_k p_{ikj} y_{ij}$ is the expenditure on meat category j by household i in period t, and $z_{ijct} = \sum_k a_{kjc} y_{ikjt}$ is the amount of nutrient c household i obtains from category j in period t.

5.2 Endogeneity of the nutritional content

Note that purchased quantities appear both on the left-hand side of the equation in $\omega_{ijt} = \sum_k p_{ikj} y_{ikj}$ and on the right-hand side in $z_{ijct} = \sum_k a_{kjc} y_{ikj}$. This creates an endogeneity problem, biasing the estimates of the coefficients related to nutritional content. We instrument for z_{ijct} to correct for this endogeneity. Following Dubois et al. (2014), we use the exogenous variation in available products, which can be due to product entry and exit, to product shelf availability at a certain point in time and a certain local market or retailer, or to changes in market structure. The changes in availability are valid instruments if they are exogenous conditional on the controls for household heterogeneity in preferences.

We do not directly observe product (or nutrient) availability, but we can use the nutritional composition of household choices as a proxy for nutrient availability. We construct the instruments in the following way. We assign each household to a reference group, depending on geographical area and favorite retailer (most frequently visited retailer in a certain year, which means that a household's reference groups are year specific). The geographical areas are the 21 administrative regions of metropolitan France at that time. We then list all meat products purchased by at least one household from the reference group in a certain period. We interpret this list as an approximation of the set of available meat products for households in that reference group during that period. We compute the average nutritional content (unweighted by quantities or frequency of purchase) across products for each of the different meat categories. Our instrumental variables are these averages per nutrient and meat category. Note that they vary per household, category, and period. Moreover, they are correlated with the purchases' nutritional content but uncorrelated with the residual of households' quantity choices.

Because the safety shock affects consumers' preferences and because the products available in a certain market are likely correlated to consumers' preferences, one may worry about the exogeneity of the above instruments in our application. However, we explicitly control for the shock in safety perception, so the safety shock is not captured by the residuals, which would create correlation between the instruments and the residuals.

Figure 3 illustrates how the instruments for the different nutrients vary across periods and reference groups. We observe that the instrumental variables for beef and veal vary considerably across periods, regions and stores. Similar variation exists for other categories. Note also that the safety shock in October 2000 does not seem to affect the variability of the instruments, implying there is no evidence that the shock affected nutritional availability.

6 Results

In this section, we first present the demand estimation results, then present the counterfactual exercises and their results.

In the demand model and similar to the previous analysis, we consider 6 separate product categories: beef and veal, offal, poultry, pork, fish, and other. We let the value of consumers' safety perception vary after the crisis for the categories of beef and veal, and offal. The safety perception of other product categories is assumed to remain unchanged.

During the period of analysis, consumer prices for fresh food increased by more than 3% every year for reasons unrelated to the October 2000 events (INSEE (2007)). Because in the estimation we are interested in capturing the responses to changes in real prices (prices of meat products relative to other food products), we deflate prices using the weekly consumer price index for all meat products in metropolitan France. Due to the time-period fixed effects, the coefficient estimates in the demand estimation should not be affected by the deflator, but using real prices instead of nominal prices makes a difference in the counterfactual exercises that simulate purchased quantities if prices were the same as before the event. As the nominal prices of fresh food products increased persistently during the period under study, the simulated quantities would be underestimated if we used nominal prices (because the nominal prices are higher than the real prices and increasing over time).

6.1 Utility parameter estimates

Table 9 presents the utility parameter estimates. The left-hand side variable is households' expenditure per four-week period in euros. The first column reports OLS estimates and the second column, estimates using instrumental variables. All equations include household-category fixed effects that measure the household-specific taste for the category.[17]

In both specifications, we observe a significant decline in the safety perception of beef, veal and offal during the three months after the event, as can be inferred by the negative and significant shocks to these categories in the three 4-week periods after the event. We also find that nutritional characteristics significantly affect consumers' preferences. The estimated coefficient

[17] Although not presented in the paper, we obtain very similar results when also including interactions between seasons and household-category fixed effects.

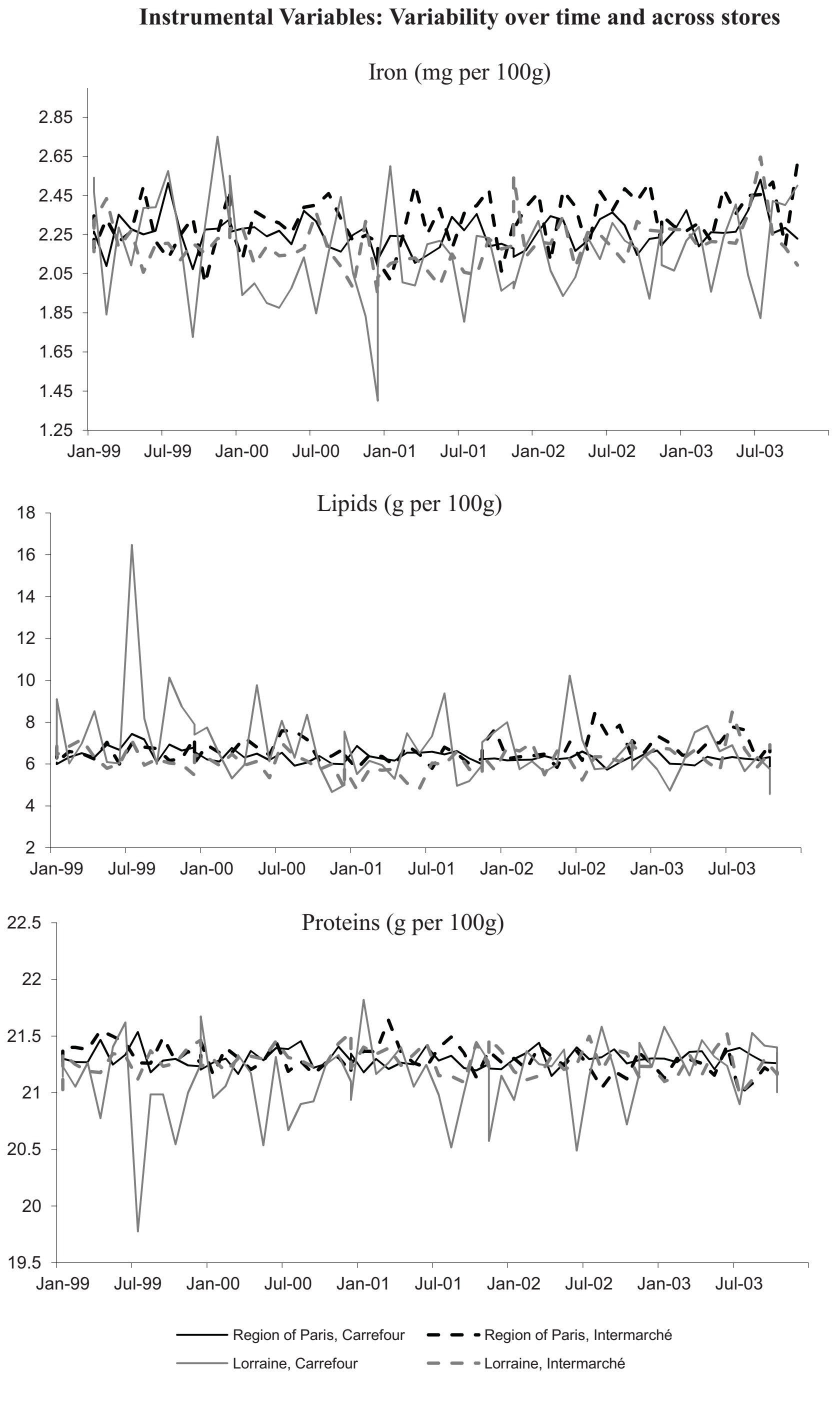

Figure 3: Source: scanner data. Monthly average nutrient content of beef and veal products available in the corresponding favorite store. The units of iron are in mg per 100 grams, and the units of lipids and proteins are in grams per 100 grams of meat, 1999-2003.

for iron is positive and significant in both specifications, with a higher coefficient being obtained when we use instrumental variables. Consumers also derive utility from proteins and lipids, but the signs of the estimated coefficients change when we correct for the endogeneity of nutritional content. In the IV regression, proteins have a negative impact on utility whereas lipids have a positive impact. The negative coefficient for proteins may initially appear surprising, but it is likely related to the fact that all meat categories are highly protein-rich and there is little protein content variation across them (see Table 2). Furthermore, this negative coefficient could be related to the excessive protein intake in developed countries mentioned in Section 3. In what concerns the coefficient for lipids, note that the nutrient parameters can also capture taste for the flavor of the nutrient, not only health concerns. Our model includes household taste for the category but not household taste for each of the different cuts. Thus, the lipids, for instance, may be capturing that households like the taste of fat in meat (for instance, they may prefer more marbled red meat cuts to leanest cuts).

An advantage of the model is that it allows us to recover households' individual unobserved preferences per category, δ_{ij}. Table 5 reports the estimates of δ_{ij}, averaged across households. The average household's favorite category is poultry, followed closely by beef and veal. Its least favorite category is offal. Taste for fish is relatively high and comparable to the taste for pork, but its standard deviation is also high. Using these estimates, in the next section we conduct counterfactual exercises that quantify the importance of the taste for beef products on consumers' response to the safety crisis.

6.2 Counterfactual exercises

6.2.1 Counterfactual 1: consumer reaction due to the safety shock

This first counterfactual isolates the effect of the change in safety perceptions from changes in prices and product attributes. The exercise simulates average monthly purchased quantities in the six months after the event if there were no shocks to the safety perceptions of consumers. In addition to the effect on the average household, we also study households' heterogeneous responses to the safety shock.

Isolating quantities in equation (3), taking averages and using estimated parameters, we get the observed average monthly quantities purchased by the average consumer:

$$\bar{y}_j = \left(\sum_{t=\tau}^{6} \mathbb{1}_{j=b} \hat{\psi}_t + \hat{\delta}_j + \hat{\xi} + \hat{\epsilon}_j \right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_{k_t} a_{kjc} \right) \tag{4}$$

where:

$$\bar{y}_j \equiv \frac{1}{6N} \sum_{i=1}^{N} \sum_{t=\tau}^{6} y_{ijt},$$

$$\bar{p}_j \equiv \frac{1}{6N} \sum_{i=1}^{N} \sum_{t=\tau}^{6} p_{ijt};$$

that is, $\bar{y}_j$ and $\bar{p}_j$ are the average monthly quantity purchased and the average price paid by the average household over the six months after the event. The hat above a parameter indicates its estimated value. In particular, $\hat{\xi}$ is the average estimated time fixed effect for the six-months period and $\hat{\epsilon}_j$ is the average estimated household-category-specific time fixed effect over the six-months period. Also, τ is the month when the event happens, (i.e., October 2000), and N is the number of consumers.

To obtain the simulated average monthly purchased quantities in the six months after the event by the average consumer if there were no shocks to the safety perceptions of consumers, we let the shock in consumers' safety perception, ψ_t, be zero throughout the six months. We denote these simulated quantities as $\bar{q}(No\ shock)_j$:

$$\bar{q}(No\ shock)_j = \left(\hat{\delta}_j + \hat{\xi} + \hat{\epsilon}_j\right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_{k} a_{kjc}\right). \tag{5}$$

We compare $\bar{q}(No\ shock)_j$ and the actual purchased quantities $\bar{q}_j$ in (4). The percentage differences are calculated as:

$$\frac{\bar{q}(No\ shock)_j - \bar{q}_j}{\bar{q}(No\ shock)_j}.$$

Table 6 reports the results for this hypothetical scenario in which there is no shock to consumers safety perception of beef and veal and offal after the event. The table shows simulated and observed average monthly quantities purchased of beef and veal and offal after the event by the average consumer, as well as the percentage differences between the simulated and observed quantities.

If the average household had not changed its belief about product safety, the average monthly purchase of beef and veal in the six months after the event would have been approximately 9% higher than the observed quantities after the event. In the case of offal, average monthly quantities would have been 27% higher than observed if there was no shock to safety perceptions.

In order to get a monetary measure of the impact of the safety information shock, we also calculate the variation in prices that would lead to the same quantity variation as the safety shock. Hence, we calculate the following counterfactual prices:

$$\bar{p}(No\ shock)_j = \left(\sum_{c=1}^{C} \hat{\beta}_c z_{ijct} + \hat{\delta}_{PL} + \hat{\xi} + \hat{\epsilon}_b\right) / \bar{q}(No\ shock)_j. \tag{6}$$

The price $\bar{p}(No\ shock)_j$ answers the question: which price would lead to the same quantities observed after the safety shock in case there was no safety shock? Table 7 shows that the price of beef and veal would have to be 17% higher than observed prices after the crisis to lead to the same drop in quantities as the safety shock. This implies a price-elasticiy of demand of around -0.53, indicating that the demand for beef and veal is not very elastic.[18] In the case of offal, the price would have to increase 42% to lead to the same drop in quantities.

[18] This elasticity for beef and veal is in line with other measures in the literature. Okrent and Alston (2012) find that the beef price-elasticity in the US is -0.7, and Boizot-Szantai and Sans (2014) find the beef price-elasticity between -0.4 and -0.6 for France.

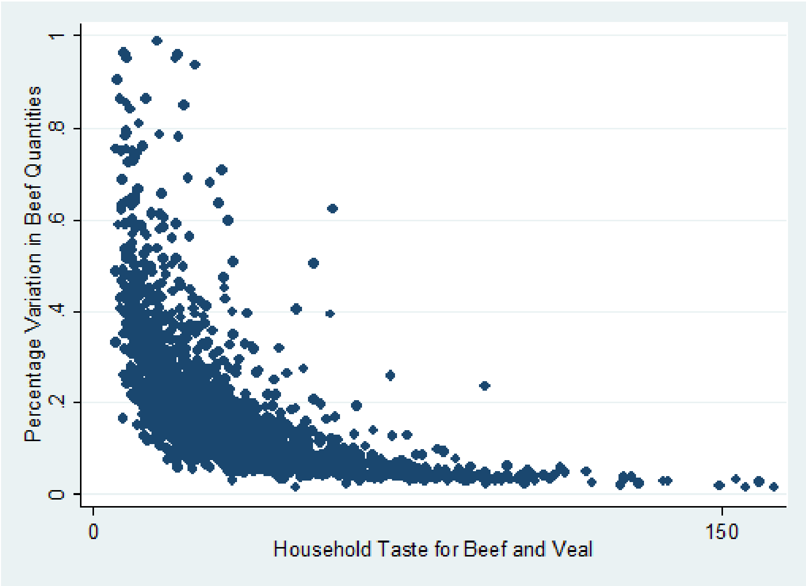

Figure 4: Relation between households' taste for beef and their percentage variation in quantities consumed relative to a situation without the safety crisis

The above counterfactual is calculated for the average consumer. However, there is substantial heterogeneity in consumers' responses to the safety shock. To illustrate how individual responses correlate relate to tastes, we now calculate simulated quantities for each household and compare them to household-level observed quantities (so we use an equation similar to 6 but without averaging quantities across households). Figures 4 and 5 plot the percentage variation between simulated and observed quantities per household against households' unobserved tastes for beef and veal, and offal, respectively. It is clear from the graphs that for even if consumers experience the same decrease in safety perception, their responses are very heterogeneous. Also, there is a large group of consumers (in the upper tail of the taste distribution) that do not respond to the safety shock.

6.2.2 Counterfactual 2: consumer reaction due to tastes

Counterfactual 2 sheds light on the role of consumers' preferences in the response to the safety crisis and on the utility costs associated with having to avoid a product they enjoy, independent of its nutritional characteristics. If consumers like a product, forgoing its consumption may represent an important utility loss. Thus, even if the consumer perceives the product to be potentially unsafe or of bad quality, there may be resistance to reducing consumption of it. The exercise also provides an idea of the size of the demand effect that we should expect in cases in which food safety crises involve other meat categories.

The counterfactual exercise uses the household-specific taste per category estimated in the demand model and reported in Table 5. We simulate monthly purchased quantities of beef and veal and offal in the six months after the mad cow crisis if households liked beef and veal

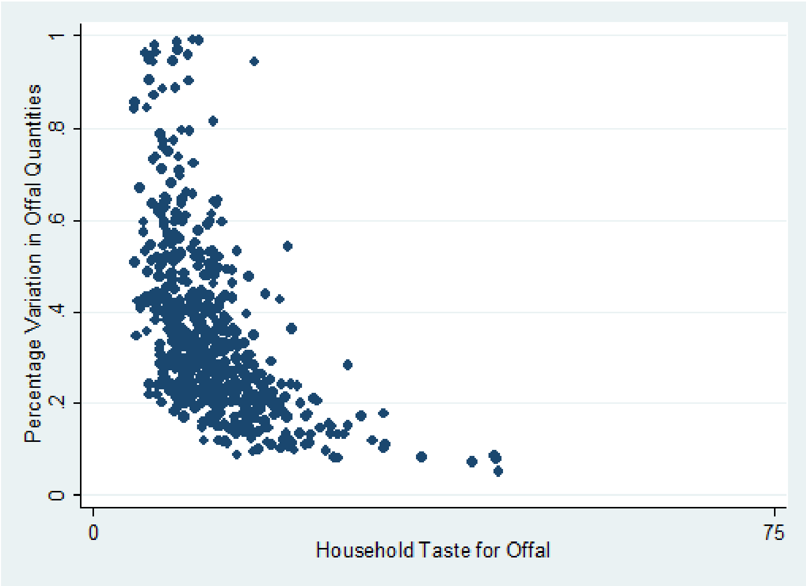

Figure 5: Relation between households' taste for offal and their percentage variation in quantities consumed relative to a situation without the safety crisis

and offal as much as they like pork (the least favorite category, if we exclude offal). We then compare the simulated quantities to the observed average monthly quantities.

As in the previous counterfactual, the observed average monthly quantities purchased by the average consumer are given by Equation 4. The simulated monthly purchased quantities of beef and veal and offal in the six months after the mad cow crisis if households liked beef and veal and offal as much as they like pork are given by

$$\bar{y}(Pork)_b = \left(\sum_{t=\tau}^{6} \mathbb{1}_{j=b}\hat{\psi}_t + \hat{\delta}_{Pork} + \hat{\xi} + \hat{\epsilon}_b\right) / \left(\bar{p}_b - \sum_{c=1}^{C} \hat{\beta}_c \sum_{k_{t1}} a_{kbc}\right), \tag{7}$$

where $j = b$ indicates beef and veal, or offal. The difference between the quantities in (4) and the simulated quantities in (7) is that in the latter equation, when $j = b$ (that is, when the product belongs to the beef and veal or offal category), we replace $\hat{\delta}_j$, the estimated unobserved taste for j, with $\hat{\delta}_{Pork}$, the estimated unobserved taste for pork. Hence, in (7) we calculate the average monthly quantities of beef, veal and offal that would have been purchased by the average consumer in the period following the event if the average consumer's taste for beef and veal and offal had been the same as his taste for pork.[19]

[19]Note that to isolate the effect coming exclusively from households' tastes, this counterfactual exercise maintains nutrients and prices as in beef. Alternatively, we could conduct a related counterfactual exercise comparing purchased quantities of pork after the crisis with and without the safety shock. That is, we would compare the observed average monthly purchased quantity of pork during the six months after the event and the (simulated) quantity that would have been purchased had there been a shock to safety perceptions af-

As before, we calculate percentage differences between simulated and actual quantities in the following way:

$$\frac{\bar{y}(Pork)_l - \bar{y}_l}{\bar{y}(Pork)_l}$$

$$\frac{\bar{y}(Pork)_{jt} - \bar{y}_{jt}}{\bar{y}(Pork)_{jt}}.$$

Table 8 reports the results for Counterfactual Exercise 2, in which simulated quantities are obtained when we replace households' taste for beef and veal and offal with the estimated taste for pork. Comparing simulated and observed quantities after the crisis, we see that purchases of veal would have been 23% lower if the average household had liked beef and veal as much as it likes pork. This means that demand for beef and veal would have declined by a total of 32% (instead of 9%) following the safety crisis (comparing observed quantities before the crisis and simulated quantities after the crisis) if the average consumer liked beef and veal as much as it likes pork. For the case of offal, the demand would have actually increased because the average household's taste for offal is below it taste for pork, as shown in Table 5. Given that offal is, by a large margin, the least preferred category, its demand would have increased by 66% if the average household liked offal as much as it likes pork. This effect on the change in tastes is actually larger than the 27% increase that we find in the absence of a safety shock.

Can we obtain a measure of the importance of tastes in limiting the quantity reaction in monetary terms? To do so, we calculate the price level that leads to the same purchased quantities as (7) but maintaining the actual estimated tastes for the beef and veal and offal categories. That is, we calculate the following counterfactual price:

$$\bar{p}(Pork)_b = \left(\sum_{t=\tau}^{6} \mathbb{1}_{j=b} \hat{\psi}_t + \sum_{c=1}^{C} \hat{\beta}_c z_{ijct} + \hat{\delta}_{PL} + \hat{\xi} + \hat{\epsilon}_b \right) / \bar{q}(Pork)_b.$$

Table 9 shows the importance of taste in limiting demand in monetary terms. The simulated price is the price that would lead to the same decline in demand as a change in tastes (the price that would lead to the quantities purchased by the average household if it liked beef and veal and offal as much as it likes pork). The price of beef and veal after the crisis would have to be 32% higher than the observed prices after the crisis to lead to the same quantities as a change in tastes.

For the case of offal, we find that a negative price would be required to induce the change in quantities that we would obtain if the taste for offal were the same as the taste for pork. The average household's quantity purchased would have increased considerably if it liked offal as much as it likes pork. Therefore, offal prices after the crisis would have to be 408% lower than observed prices after the crisis to lead to the same quantities as a change in tastes.

The results from Counterfactual Exercise 2 can be translated into retailers' revenue by

fecting pork instead of beef and veal and offal. In this case, the simulated quantities would be given by $\bar{y}(Pork)_{jt} = \left(\sum_{t=\tau}^{6} \mathbb{1}_{j=pork} \hat{\psi}_t + \hat{\xi} + \hat{\epsilon}_l\right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_{k_t} a_{kbc}\right)$.

multiplying the observed and simulated average monthly quantities in the six months following the event by the average monthly prices during the period. Hence, for example, if consumers' taste for beef and veal had been the same as their taste for pork, and taking prices as observed, retailers' revenues would have declined 23% further than observed, implying a larger demand reaction cost to firms.[20] This indicates that the role to be played by public policy in terms of disciplining firms in a product safety crisis depends on consumers' preferences. In the absence of close substitutes, the more consumers like a product, the higher are the utility costs of decreasing its consumption and, as a consequence, the greater the frictions in market incentives to produce safer products.

6.2.3 Counterfactual 3: consumer reaction due to nutritional characteristics

In this counterfactual exercise, we study the role of the nutritional characteristics of substitutes in conditioning households' responses to the safety threat. We measure how consumers would have reacted to the product-harm crisis if poultry, their favorite meat category along with beef and veal, had comparable nutritional characteristics to beef and veal, and offal.[21] Specifically, we answer the following question: how much would the average consumer have bought of the affected categories after the crisis if 1 kg of the affected category had the same nutritional characteristics, on average, as 1 kg of poultry. [22] Hence, this exercise tells us how consumers would have reacted to the crisis if they could have switched to a product category with comparable nutritional value to beef.

The simulated quantities in this case are given by the equation below:

$$\bar{q}(Poultry)_{jt} = \left(\sum_{t=\tau}^{6} \mathbb{1}_{j=b}\hat{\psi}_t + \hat{\xi} + \hat{\epsilon}_l\right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_{k_t} a_{kbc}^{poultry}\right).$$

where $j = b$ indicates that the category is beef and veal and offal and $a_{kbc}^{poultry}$ is the average nutritional content of poultry.

Table 10 shows the results of this counterfactual exercise. If beef and veal had the same nutritional content as poultry, on average, consumers would have purchased 19% less meat and veal and 44% less offal after the crisis. This result shows that consumers' response to the product-harm crisis would have been much stronger if they had been able to find a closer substitute, in terms of nutritional characteristics, than poultry. [23]

[20] Note that if the taste for beef and veal were the same as the taste for pork, the effect of the mad cow crisis on prices could have differed. It is unclear what the effect on revenues would have been had prices readjusted differently.

[21] We performed the same exercise for pork, households' least preferred category after offal.

[22] Analogously, we could also have asked how much poultry the average consumer would have bought after the crisis if 1 kg of pork or poultry had the same nutritional characteristics, on average, as 1kg of beef.

[23] If beef and veal had the same nutritional content as pork, on average, consumers would have reacted even less to the crisis: they would have bought 20% more beef and veal after the crisis. This result shows that if consumers only cared about nutritional characteristics, then they would have had a close substitute to switch to as a way of avoiding consumption of the unsafe product. (However, as is clear from the results of Counterfactual 2, there is little substitution little toward pork because pork is one of the average consumers' least preferred categories.)

6.2.4 Counterfactual 4: consumer reaction due to changes in prices

This counterfactual exercise compares observed quantities to simulated average monthly purchased quantities per category if average prices had remained the same in the six months after the event. This isolates the effect of price changes on quantity choice per category from changes in safety perception and product attributes. Note that as shown in Section 3.1, we find that prices varied little following the safety crisis. Hence, we expect to find little difference between observed and expected quantities.

The simulated average monthly purchases per category j if average prices had remained the same in the six months after the event are calculated as follows:

$$\bar{q}(I)_j = \left(\sum_{t=\tau}^{6} \mathbb{1}_{j=b} \hat{\psi}_t + \hat{\delta}_j + \hat{\xi} + \hat{\epsilon}_j \right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_k a_{kjc} \right).$$

The percentage differences are calculated as

$$\frac{\bar{q}(I)_j - \bar{q}_j}{\bar{q}(I)_j}$$

Table 11 reports results for the counterfactual on prices, which simulates monthly average purchased quantities per category after the event considering average prices before the event. The results indicate that changes in relative prices tend to alleviate the effect of the shock to safety. The effects are small, as expected, as prices varied little with the shock.

7 Robustness: Media coverage as a measure of changes in safety perception

In this section, we consider an alternative way to measure the shock to safety perception. Instead of exploiting the before and after variation in safety perception due to the mad cow event in October 2000, we consider the intensity of the media coverage of the mad cow crisis. The assumption here is that news stories provide new information on the product safety crisis and that consumers pay attention and accordingly update their beliefs regarding safety. An alternative and, for our purposes, equivalent assumption would be that the number of news stories in a certain period is a proxy for the amount of public information on the safety crisis during that period. Under this assumption, the frequency of media coverage is an alternative means of identifying changes in consumers' product safety perception without relying on observing the abrupt event that triggers the safety crisis

The estimable equation is the same as before except that the change in safety perception, rather than being captured by $\sum_{t=\tau}^{T} \mathbb{1}_{j=b} \psi_t$, is now captured by a continuous variable measuring the number of news stories in the French press that mention the mad cow crisis and meat, n_t. Hence, the estimable equation is

$$\omega_{ijt} = \sum_{c=1}^{C} \beta_c z_{ijct} + \sigma_j n_t + \delta_{ij} + \xi_t + \epsilon_{ijt},$$

where n_t is a continuous variable that counts the number of news stories mentioning mad cow and meat in the French written press, and σ_j is a category-specific parameter to be estimated.

Table 12 reports results from a specification that lets $\sigma_j = \sigma$ for all categories j except for beef and veal and offal, for which $\sigma_j = \sigma_b$. The specifications test the null of whether $\sigma_b = \sigma$. The first column reports OLS results with household-category fixed effects, whereas the second column shows results from an IV estimation with household-category fixed effects. We used the same instrumental variables as previously, which control for the availability of nutrients across markets and periods, as described in section 5.2.

Our main results are robust to this new specification. As before, we obtain significant coefficients for products' nutritional characteristics. The signs of the coefficients are consistent with the results in Table 12, indicating that consumers like lipids and iron but dislike proteins. The common coefficient on the number of news stories is small but positive and significant, suggesting that news stories on mad cow do not have a negative effect on consumers' safety perception of meat in general. However, focusing specifically on beef, veal and offal, the coefficient on news stories is higher in magnitude and significantly negative. This indicates that preferences for beef and veal (including offal) are negatively affected by the number of news stories, which we interpret here as a measure of changes in consumers' safety perception.

8 Impact on basket of characteristics

In this section, we investigate the effects of the mad cow event on consumers' nutritional basket. Table 13 reports the effects of the event on the mean nutritional content of households' meat purchases. In the table, the dependent variables are the mean nutritional contents per 100 g of meat (all categories, including fish) purchased per household each month. We observe that the nutritional content changes after the event. The iron content per 100 g of meat purchased decreases significantly in the four months after the event, which mirrors the decline in purchases of beef and veal and indicates that larger quantities of meat have to be consumed to maintain the same total amount of iron consumed per month (as can be seen in Table 14, we also observe a decline in the monthly amount of iron obtained from meat per household.) In addition, the protein average content of household meat purchases increased in the 4 months after the events. This is likely due to an increase in the consumption of poultry, which has high average levels of protein. This is not necessarily beneficial for consumers because nutritional research shows that the typical diet in developed countries already includes too much protein.[24] Excessive protein intake can have negative health consequences, including reduced energy, kidney disease, and osteoporosis, and can even cause some cancers.[25] The variation in lipids is less clear, exhibiting sporadic increases in some months following the event.

The above results show that the consumer reaction to the crisis affects not only purchased

[24]For example, Americans eat, on average, twice the recommended daily amount of protein. National Center for Health Statistics, http://nchstats.com.

[25]United States. Centers for Disease Control and Prevention. "Nutrition for Everyone: Protein." Oct. 4, 2012, www.cdc.gov/nutrition/everyone/basics/protein.html.

quantities of meat but also the nutritional composition of the food basket. Because of the importance of iron in consumers' diet and because our demand estimates show that consumers obtain positive utility from iron, we examine iron consumption in more detail by looking at the total amount of iron from both meat and plant products. We find that the total amount of iron consumed from meat decreases significantly after the event and seems to last several periods, as shown in Table 14 (third column).

We investigate the degree to which consumers replaced animal-source iron with plant-source iron after the crisis, focusing on purchases of the main plant sources of iron: lentils, spinach, chickpeas, and other high-iron beans. The first column of Table 14 shows the results of a regression in which the dependent variable is the household monthly quantity purchased (in kg) of lentils, spinach, chickpeas, and other beans. The second and third columns show results of the regressions of the household monthly amount of plant foods (spinach, lentils, chickpeas, and other beans) and iron consumed from animal (all meat categories), respectively. That is, the amount of iron per gram in each product times the quantity purchased of each product summed over the animal and plant foods considered. All equations include household fixed effects and period fixed effects.

We see that although consumers increase their consumption of some iron-rich plant foods in the period following the product safety event, this increase is short lived, lasting only one 4-week period. The results for iron consumption indicate that variation in purchases of iron-rich plant foods leads to a negligible increase in the consumption of iron from plant sources (second column of Table 14). This is especially notable because we find that approximately one-half of households below the median level of iron consumption from animal sources are also below the median level of consumption from plant sources.

9 Conclusion

This paper formalizes and quantifies the tradeoffs that consumers face in responding to product-harm crises. Understanding the effect of these tradeoffs on demand is critical for designing better managerial and institutional strategies to deal with such crises. In a market without close substitutes for the affected product, we find that avoiding purchases of the unsafe product can lead to substantial utility loss for consumers. Our demand estimates show that consumers significantly care for products' nutritional characteristics and safety level. The estimation results show that idiosyncratic taste is a crucial driver of consumers' responses, such that consumers face a tradeoff between their preference for the product's observable characteristics and their taste for the product itself. One implication of this tradeoff is that the observed substitution patterns after the crisis negatively impact the consumers' food basket's nutritional composition.

Using the utility parameter estimates, we conduct counterfactual exercises to disentangle the relative importance of the different drivers of the decline in demand. Specifically, the counterfactual exercises quantify how the different components of consumers' preferences limit the response to the safety crisis. We find that the unsafe category is among consumers' most preferred product categories, which contributed to the relatively weak demand reaction. If consumers had liked the category less (e.g., as much as they like an intermediate category), the decline in demand would have been more severe. Consumers' response is also limited by the lack of close substitutes in terms of observable nutritional characteristics: demand for the affected product would have declined significantly further if consumers had access to alternative products with similar nutritional composition. These results indicate that consumers weigh the losses from shifting away from their preferred basket against the disutility of being exposed to a potentially unsafe product, and this tradeoff limited the demand reaction to the crisis.

Managerial implications

Our results have several implications for the design of managerial responses to product-harm crises. First, firms should be aware that immediate (and even medium-run) demand responses do not generally reflect the severity of the crisis in consumers' valuations. In particular, when the crisis is industry wide or spills across brands in the industry, consumers' responses are constrained by their idiosyncratic taste for the affected product and by the costs of substituting to alternative products with different characteristics. As our results show, using sales as an indicator could lead to the incorrect conclusion that consumers still buying the product are not affected by the safety shock or do not update their safety perceptions. Those consumers could actually have a "foot out the door," waiting for the entry of new products, for example, to switch away.

Second, firms should take into account that, although products' observed characteristics are an important determinant of consumers choices, substitution patterns seem to be substantially driven by consumers idiosyncratic tastes. Indeed, in our application, we find that consumers substitute mainly from beef and veal to poultry, although other product categories (e.g., pork) have more comparable nutritional characteristics. This implies that understanding the relative importance of the different demand drivers (price, product characteristics, safety, and taste) in consumers' choices is crucial to assessing the intensity of the consumers' response. Also, the analysis of heterogeneity in consumer responses permits to design tailored strategies to handle product-harm crises. Furthermore, by recovering consumers' preferences, firms can identify which product categories are prone to face stronger demand contractions following a crisis.

Finally, note that our analysis can be used more broadly to study any information shock affecting products' health risks, for instance, to evaluate consumers' response to health recommendations regarding the consumption of certain goods (e.g., carcinogens in food, the risks of excessive sugar intake, the effects of the consumption of palm oil).

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Table 1: Average quantity purchased per month and household, average category prices, average number of households purchasing each category per month, and average monthly volume market share per category

category	monthly quantity per household (in kg)	average price	average number of households	volume market share
beef and veal	1.92	10.29	1754.46	0.281
offal	0.77	9.25	286.99	0.018
poultry	2.12	6.68	1535.30	0.272
pork	1.70	6.03	1263.60	0.181
fish	1.95	9.54	1014.60	0.165
other	1.30	9.95	761.45	0.084

There are 3618 households that buy at least one kind of fresh meat or fish product.

Table 2: Nutrients price and content across meat categories

			Beef	Veal	Offal	Poultry	Pork	Fish	Other
Iron									
	content	(mg per 100g)	2.63	1.12	4.54	1.13	1.57	1.9	2.44
	price	(euros per 1mg)	0.38	1.14	0.2	0.57	0.36	0.72	0.39
Lipids									
	content	(g per 100g)	7.00	4.3	5.8	5.1	12.2	3.1	9.8
	price	(euros per 1g)	0.15	0.29	0.16	0.14	0.05	0.32	0.11
Proteins									
	content	(g per 100g)	21.4	20.8	18.1	27.2	24	19	24.9
	price	(euros per 1g)	0.05	0.06	0.05	0.03	0.02	0.05	0.04

Table 3: Changes in prices and market shares of beef and veal after the event

	Beef and Veal			Poultry			Pork		
	Price Index		Market	Price Index		Market	Price Index		Market
	Variable	Fixed	shares	Variable	Fixed	shares	Variable	Fixed	shares
1 month after X category	0.11	-0.36	-0.09***	0.00	0.25	0.04**	0.15	-0.22	0.01
	(0.63)	(0.57)	(0.02)	(0.64)	(0.57)	(0.02)	(0.68)	(0.58)	(0.02)
2 months after X category	-0.22	-0.35	-0.13***	-0.01	0.28	0.07***	-0.42	-0.12	-0.04*
	(0.63)	(0.57)	(0.02)	(0.64)	(0.57)	(0.02)	(0.68)	(0.58)	(0.02)
3 months after X category	-0.2	-0.25	-0.08***	-0.07	0.26	0.02	-0.72	-0.71	0.01
	(0.63)	(0.57)	(0.02)	(0.64)	(0.57)	(0.02)	(0.68)	(0.58)	(0.02)
4months after X category	-0.13	-0.26	-0.03	0.01	0.33	0.01	0.17	-0.16	0.01
	(0.63)	(0.57)	(0.02)	(0.64)	(0.57)	(0.02)	(0.68)	(0.58)	(0.02)
5 months after X category	-0.19	-0.33	-0.03	-0.14	0.39	0.03*	0.27	-0.03	-0.01
	(0.63)	(0.57)	(0.02)	(0.64)	(0.57)	(0.02)	(0.68)	(0.58)	(0.02)
6 months after X category	-0.32	-0.55	-0.03	-0.43	0.23	0.03	0.53	0.36	-0.03
	(0.63)	(0.57)	(0.02)	(0.64)	(0.57)	(0.02)	(0.68)	(0.58)	(0.02)
7 months after X category	-0.27	-0.66	-0.01	-0.42	0.1	0.03	0.39	0.19	-0.01
	(0.63)	(0.57)	(0.02)	(0.64)	(0.57)	(0.02)	(0.68)	(0.58)	(0.02)
8 months after X category	-0.16	-0.59	-0.04**	-0.38	0.34	0.02	0.45	0.54	0.02
	(0.63)	(0.57)	(0.02)	(0.64)	(0.57)	(0.02)	(0.68)	(0.58)	(0.02)
Category FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	325	325	325	325	325	325	325	325	325

Standard errors in parentheses;* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; prices are in euros, and market shares are in volume; 't months after X category' is a dummy variable that indicates purchases of the category (beef and veal, poultry, or pork over 't' months after the events, t=1,...,10.

Table 4: Utility parameter estimates

	(1)		(2)	
	OLS-FixedEffects		IV-FixedEffects	
proteins	0.03***	(0.00)	-0.05***	(0.02)
lipids	-0.01***	(0.00)	0.03***	(0.01)
iron	1.60**	(0.67)	2.50**	(1.09)
Month 1 X b/v	-0.24	(0.23)	-4.86***	(1.27)
Month 2 X b/v	-1.71***	(0.27)	-10.60***	(2.01)
Month 3 X b/v	-0.86***	(0.22)	-4.29***	(0.94)
Month 4 X b/v	-0.43**	(0.21)	-0.79	(0.75)
Month 5 X b/v	-0.09	(0.18)	-0.83	(0.74)
Month 6 X b/v	-0.30	(0.22)	-1.67***	(0.56)
Month 7 X b/v	-0.55***	(0.18)	-1.23*	(0.63)
Month 8 X b/v	-0.63**	(0.27)	-3.58***	(1.08)
Period FE	Yes		Yes	
Weak IV test			12.72	
N	423210		422102	

All specifications include year, quarter and season fixed effects;
The first column reports estimates of OLS with household-category fixed effects; while the third column shows estimates of a model with instrumental variables and household-category fixed effects.
The weak IV test is the Kleibergen-Paap Wald F-statistic.
"b/v" refers to beef and veal (including offal); "t months after X b/v" is a dummy variable indicating purchases of beef and veal 'x' months after the event. Standard errors (in parentheses) are clustered at the category-region level.
- * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Estimated taste per category of the average household

	average household	
beef and veal	31.32	(20.43)
offal	11.83	(5.80)
poultry	33.81	(18.83)
pork	23.50	(11.42)
fish	24.80	(17.39)
other meat	22.81	(10.61)

Standard deviations of mean taste in parentheses

Table 6: Counterfactual 1 - Average consumer's simulated monthly purchased quantities in the six month after the event if there was no change in safety perception

Category	simulated q	observed q	% variation
Beef and Veal	2.132	1.934	9%
Offal	0.989	0.724	27%

Quantities are in kg.

Table 7: Counterfactual 1b - Price level that leads to the same purchased quantity of the quantity shock, but if there was no safety shock

Category	simulated price	observed price	% variation
beef and veal	11.23	9.35	17%
offal	11.91	6.89	42%

Prices are in euros per kg.

Table 8: Counterfactual 2 - Average consumer's simulated monthly purchased quantities in the six month after the event if the taste for beef, veal and offal was the same as the taste for pork

	simulated q	observed q	% variation
beef and veal	1.572	1.934	-23%
offal	2.157	0.725	66%

Quantities are in kg.

Table 9: Counterfactual 2b - Price level that leads to same purchased quantity after the safety shock as if taste for beef, veal and offal was the same as taste for pork

	simulated price	observed price	% variation
beef and veal	13.61	9.35	32%
offal	-2.24	6.89	-408%

Prices are in euros per kg.

Table 10: Counterfactual 3 - Average consumer's simulated monthly purchased quantities in the three months after the event if the average nutritional content per kg of beef, veal and offal was the same as poultry

	simulated q	observed q	% variation
beef and veal	1.618	1.934	-19%
offal	0.497	0.725	-44%

Quantities are in kg.

Table 11: Counterfactual 4 - Average consumer's simulated monthly purchased quantities in the six month after the event if prices were the same as before the event

Category	simulated q	observed q	% variation
Beef and Veal	1.936	1.934	0%
Offal	0.729	0.725	0.6%
Poultry	2.346	2.313	1.4%
Pork	1.723	1.691	1.9%
Fish	2.057	2.034	1.1%
Other	1.390	1.337	3.8%

Quantities are in kg.

Table 12: Demand Estimates - Alternative specifications considering number of newspaper stories mentioning Mad Cow

	(1) OLS-Fixed Effects		(2) IV-Fixed Effects	
proteins	0.03***	(0.00)	-0.05***	(0.01)
lipids	-0.01***	(0.00)	0.02***	(0.01)
iron	1.60***	(0.03)	1.97**	(0.95)
nb of newspapers articles	0.14***	(0.02)	0.47***	(0.09)
nb of newspapers articles X b/v	-0.15***	(0.03)	-1.45***	(0.28)
Weak IV test			15.62	
N	423210		422102	

"nb of newspapers articles" is the monthly number in hundreds of newspaper articles published in the French written press mentioning the words "mad cow" ("vache folle") and "meat" ("viande"); b/v means beef and veal (including offal).
All specifications include year, quarter and season fixed effects. The first column reports estimates of OLS with household-category fixed effects; while the third column shows estimates of the model with instrumental variables and household-category fixed effects.
The weak IV test is the Kleibergen-Paap Wald F-statistic. "b/v" refers to beef and veal (including offal); "t months after X b/v" is a dummy variable indicating purchases of beef and veal 'x' months after the event. Standard errors (in parentheses) are clustered at the category-region level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 13: Change in nutritional content of purchased meat baskets after the event

	Proteins	Lipids	Iron
1 month after	0.31***	-0.28***	-0.11***
	(0.05)	(0.07)	(0.02)
2 months after	0.28***	-0.11	-0.11***
	(0.06)	(0.08)	(0.03)
3 months after	-0.05	-0.00	0.01
	(0.07)	(0.10)	(0.03)
4 months after	0.22***	0.16	-0.06*
	(0.07)	(0.10)	(0.03)
5 months after	0.30***	-0.01	-0.10***
	(0.07)	(0.10)	(0.03)
6 months after	-0.05	-0.14	0.01
	(0.07)	(0.10)	(0.03)
7 months after	0.08	-0.07	0.01
	(0.07)	(0.10)	(0.03)
8 months after	0.25***	0.22**	-0.01
	(0.07)	(0.10)	(0.03)
Year and Season FE	Yes	Yes	Yes
N	145866	145866	145866

Notes: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, 't months after' is a dummy variable that indicates 't' months after the events. Proteins and lipids are in g per 100 grams. Iron is in mg per 100 grams

Table 14: Monthly household consumption of iron-rich plants, and total amount of iron from plant and animal sources

	Quantity of iron-rich plants	Total iron from plants	from meat
1 month after	0.039*	0.61	-6.05***
	(0.203)	(0.47)	(1.94)
2 month after	0.002	0.30	-0.10
	(0.025)	(0.57)	(2.15)
3 month after	-0.01	-0.41	-9.80***
	(0.036)	(0.83)	(2.71)
4 month after	-0.058	-1.00	-19.17***
	(0.036)	(0.83)	(2.71)
5 month after	-0.052	-0.83	-20.57***
	(0.036)	(0.83)	(2.70)
6 month after	-0.040	-0.82	-5.17*
	(0.036)	(0.84)	(2.67)
7 month after	-0.060	-1.34	-15.28***
	(0.037)	(0.86)	(2.67)
8 month after	-0.077**	-1.57*	-15.54***
	(0.038)	(0.88)	(2.66)
Household FE	Yes	Yes	Yes
Period FE	Yes	Yes	Yes
N	50255	50255	145866

Standard errors in parentheses;* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The dependent variables in the first, second, and third columns are, respectively: household monthly purchases of lentils, spinach, chickpeas, and other beans (in kg); total iron consumed from the above plant sources per month and household (in mg); and total iron consumed from animal sources (meat) per month and household (in mg); "t months after" is a dummy variable indicating 'x' months after the event; time period fixed effects consists of quarter, Christmas season, and year.