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CONSUMERS' COSTLY RESPONSES TO PRODUCT HARM CRISES

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INDUSTRIAL ORGANIZATION

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Consumers' Costly Responses to Product-Harm Crises*

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Abstract

Exploiting 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, product characteristics, and prices—driving consumers' responses. We find that consumers' reaction is limited by their preferences for the product observable and unobservable characteristics. Due to the costs associated with switching 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. We find that, in the specific crisis we study, the demand would have declined 19% further if consumers had had access to a closer substitute in terms of product characteristics and 23% further if consumers' idiosyncratic unobserved taste for the affected product category was as low as that for one of the main substitute categories. For an accurate assessment of product-harm crises, 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
JEL Classification: L51, L66, K13, M3

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. However, does the drop in sales fully reflect the underlying value loss for firms? Consumers' responses must be interpreted considering not only consumers' safety concerns but also how substitutable the affected products are. Consumers' reaction can be constrained due to the lack of close substitutes to the affected product, as it can be the case when products are highly differentiated or when the crisis affects a substantial fraction of producers within the same product category.[2] As a result, the demand decrease is likely to understate the negative impact of the crisis on the affected firms' value. For a better assessment and management of product-harm crises, it is therefore fundamental to uncover the different mechanisms driving consumers' responses.

Previous literature has studied the impact of product-harm crises on firms' sales, market shares, and brand equity (Hartman, 1987; Dawar and Pillutla, 2000; Marsh et al., 2004; Ma et al., 2010; Freedman et al., 2012). However, these crises often have implications that go beyond the effect on sales and market shares, affecting, for instance, marketing effectiveness (Van Heerde et al., 2007; Liu and Shankar, 2015). Our paper contributes a deeper understanding of consumers' responses: we provide a framework to decompose and quantify the forces behind the demand drops following product-harm crises. Specifically, our approach permits measuring how much of the drop is explained by consumers' safety concerns and how much is explained by comparable utility relative to alternative products. Moreover, it permits identifying the key components that could possibly make consumers switch to potential alternatives.

We estimate a full demand model and recover the utility parameters governing the extent to which consumers care about safety, prices, nutritional characteristics, and idiosyncratic taste (i.e., everything that the consumer derives utility from that cannot be explained by observable characteristics). Counterfactual exercises isolate the roles played by each of these dimensions in consumers' demand reaction to the safety crisis. Note that although consumers safety preferences are unobservable, we are able to recover them from the data by combining our structural demand model with an exogenous change in the safety of an important food category in consumers' consumption basket. To the best of our knowledge, this is the first paper that is able

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[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] A large fraction of producers are commonly affected when the crisis is related to industry-wide practices. In such cases, brands do not prevent negative reputational spillovers to other producers, as found in Freedman et al. (2012) for the 2007 toy-recall crisis, and consistent with evidence on spillover effects across brands for automobile recalls (Borah and Tellis, 2016).

to recover consumers' safety preferences from revealed preference data. Hence, a further contribution of our work is to advance our knowledge of consumers' utility, specifically how much consumers care about safety and how elastic their demand is to changes in their product safety perception.

Our empirical analysis illustrates the key role of substitutability in consumers' responses to product-harm crises. We show how the reaction becomes stronger as alternative products with comparable characteristics become available. Taken together, our 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. In particular, this situation can be the case if product portfolios adjust to the product characteristics identified as most relevant in constraining consumers' responses.

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.[3] In addition, in this second crisis, the information was transmitted promptly to consumers, and there was limited room for consumers' behavior to be due to firms' endogenous behavior or to meat shortages.[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, which is allowed to vary across observationally heterogeneous consumers, can be identified separately from other unobservable shocks under the as-

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[3]An initial mad cow scare had occurred four years earlier, in March 1996, triggered by the UK government disclosure linking contaminated beef consumption to several human deaths in that country. Both crises had large impacts on consumption (Lesdos-Cauhapé and Besson (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 and denied on several occasions until finally confirmed in March 1996. .

[4]Based on time series data from French slaughter houses, consumption levels, and net exports in France, we observe that the crisis increased stocks of fresh meat (Lesdos-Cauhapé and Besson, 2007). Therefore, variation in sales of meat was mainly associated with the demand response and not due to stockouts of fresh cow meat in France during the months of the crisis.

sumption that safety perceptions before the mad cow disease event were constant over time. The unobserved taste for the category is household specific and comprises 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 purchase 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).

The estimation results show a considerable and significant decline in the perceived safety of beef, veal and offal in the three months after the event. In addition, our approach enables us to test whether product characteristics matters for consumers' choices. In particular, we find that nutritional composition is a significant determinant of consumers' meat choices, therefore affecting consumers' responses due to the absence of a close nutritional alternative to beef.[5]

Our results show that consumers' reactions to a safety crisis are heterogeneous and limited by how much they like the affected product. The main implications of our empirical analysis are robust to allowing for household heterogeneity in preferences for safety (or in responses to the safety shock). We find that the safety shock is heterogeneous across demographic groups, in particular, across regions. However, having controlled for household idiosyncratic taste for each meat category, we do not observe substantial differences in the changes in safety perception following the crisis across educational levels within the same geographical region.

The counterfactual exercises help isolate and quantify each of the different drivers of consumers' choices. The first counterfactual exercise isolates the effect of changes in consumers' safety perceptions to disentangle it from potential contemporaneous drivers of demand. From this exercise, we find that the purchased quantities of beef and veal would have been 9% higher, on average, if consumers had not changed their beliefs regarding product safety. We show that to produce an equivalent demand drop, the prices of beef and veal would have had to increase

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[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).

by 16%.

The second counterfactual exercise investigates the importance of idiosyncratic taste, which, as defined above, captures everything that gives consumers utility but cannot be explained by observable characteristics or changes in safety perceptions. The estimates of the unobserved taste for different categories indicate that poultry and beef are the average consumer's favorite categories, while pork and other meat are the favorite ones. We then 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 of a main substitute category (pork). The analysis shows that if the average consumer's taste for beef and veal were the same as his or her taste for pork, the average decrease in the demand for beef/veal after the safety event would have been 11% higher than the one observed. To obtain an equivalent demand variation as a response to price changes, price of beef and veal would have had to increase by almost 20%.

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, a meat category comparable to beef in terms of idiosyncratic taste but with substantial differences in terms of nutritional characteristics. We find that the demand would have declined approximately 20% further if poultry and beef (or veal) had similar nutritional characteristics. This is the demand variation we would observe as a response to an increase of 29% in the prices of beef and veal.

Counterfactual 4 quantifies the part of the demand reaction due solely to a change in relative prices (maintaining the safety level as before the crisis). In our setting, we find that the 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. This is the case because in our setting the effect of the crisis on prices is almost negligible; however, changes in relative prices after a product-harm crisis might play a more central role in other settings.

To have an approximate measure of the welfare effects of the crisis to consumers, we combine the above counterfactual exercises with an additional exercise in which we ask by how much larger the safety shock would have to be to generate the same sales drop as a product-harm crisis affecting a product consumers find easier to substitute. We find that the safety shock would have to be 65% larger to generate the same sales drop as a product consumers like less than the beef.

Moreover, the paper also studies the effect of the product-harm crisis on consumers' nutritional basket. In line with previous research studying how regulation affects consumers' and producers' product attribute tradeoffs (Knittel, 2011; Reynaert, 2015), in this section, we study how tradeoffs associated with product-harm crises may shift the product attributes composition of consumers' choices. We find that the safety crisis led to a decrease in iron consumed from animal sources. Iron is an essential nutrient for the general population, and especially for children

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and pregnant women, and beef is the product in our analysis with the highest iron content.[6] As our demand estimates show a positive and significant coefficient for iron, we study whether the shock is affecting the demand for nonmeat or fish products. We look at quantities and expenditure of products that are rich sources of iron and proteins: milk, eggs, cheese, yogurt, lentils, spinach, chickpeas, and other iron-rich beans. We find some negligible effects in the quantities or expenditures on these types of products following the crisis. Therefore, consumers do not compensate for the drop in animal-source iron with alternatives from non-animal sources.

Overall, our findings have relevant managerial implications for firms involved in product-harm crises. In many product-harm episodes, consumers face a tradeoff between their safety concerns and their preferences over the products' other characteristics. When this is the case, firms' strategies should depend on which are the main forces driving (or constraining) consumers' behavior.

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 specific product-harm crisis that we focus on and compares it to other major product-harm crisis, summarizing the main events that affected public opinion on this matter and comparing it to other relevant product-harm crises. 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 affect 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 through surveys (Morabia et al., 1999; Pennings et al., 2002; Chatard-Pannetier et al., 2004; Setbon et al., 2005) or 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

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[6]Although iron can be obtained from other types of food or from food supplements, 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.

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). In addition, while the previous literature has mostly studied the impact of product-harm crises on brands (e.g., Dawar and Pillutla, 2000; Ma et al., 2010), this paper focuses on crises where consumers' cannot avoid the affected product just by switching to alternative comparable brands. [7] These cases are particularly worth studying because it is especially costly for consumers to react to the crisis, and they might have to switch to a different product category.

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. The authors study how the effect of the recalls on brand preference depends on recall characteristics such as media attention, recall severity, and the 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). The authors 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 fraction of consumers who are 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 relatively low (see Section 2 for a comparison with other product-harm crises). Therefore, we

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[7]This is likely to be the case in highly differentiated markets or when the crisis affects a large share of firms in an industry. Among several others, see, for example, two recent prominent examples, 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).

can study frictions in consumers' responses that are not due to a lack of information.[8] 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 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 nonmonotonic 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 determine the response to the information shock and past consumption.

Our analysis may be of interest to the literature on consumers' behavioral biases.[9] 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

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[8]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.

[9]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.

average health risks that consumers face. Our approach does not rule out subjective risk. We use a model of utility-maximizing consumers conditional on consumers' perceptions. Thus, consumers' perceptions could still be subject to nonrational biases and subjective perceptions.

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 Empirical context and comparable product-harm crises

The empirical application in our analysis focuses on a product-harm crisis that involved the large majority of producers in an industry, as it originated due to an industry-wide practice. Going beyond specific particularities, our application shares features with a number of other product-harm crises. In particular, it is closely related to other crises that affected a large fraction of producers in an industry and also to product-harm crises in markets with highly differentiated products. In both of these cases, switching from the affected product(s) is likely to involve consumers giving up on the characteristics not present in the safer alternatives. Therefore, in these cases, it is particularly relevant to evaluate and quantify to what extent consumers' reaction is limited by their preferences over the (observed and unobserved) characteristics of the affected product.

In our application, we exploit an abrupt and unanticipated safety shock in France that affected beef products. As detailed below, its causes are traced to the mad cow disease and the beef industry-wide practice of using meat-and-bone cattle feed. The crisis induced consumers to switch from beef products to alternative fresh meat categories with substantial differences in terms of product characteristics. It was a sudden and unexpected product-harm crisis, as illustrated by Figure 1(a). The figure shows the evolution in the number of French newspaper articles mentioning the words "meat" and "mad cow" from December 1999 to December 2001, with a sharp increase in the number of newspaper articles observed in the figure immediately after the crisis outset in October 2000.

Figure 1(b) shows the media coverage of a comparable more recent product-harm crisis in Europe that also received considerable media attention: the 2013 horse-meat scandal (Yamoah and Yawson, 2014).[10] This latter crisis, which affected frozen ground beef, also involved a large number of manufacturers.[11] The affected products represented a large share of the market for frozen cooked dishes and, a priori, it was hard for consumers to identify which brands were

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[10]It is not straightforward to compare the media coverage between the mad cow crisis in the beginning of the 2000's and the more recent horse meat scandal because the Lexis Nexis database grew considerably between 2000 and 2013, but both scandals clearly stand out compared to the other relevant product harm crises in France, illustrated in Figure 2.

[11]"Horsemeat scandal: Withdrawn products and test results," BBC News, March 22, 2013, http://www.bbc.com/news/world-21412590 and "Horsemeat scandal: Dutch trader found guilty and jailed. BBC News April 7, 2015, en: http://www.bbc.com/news/world-europe-32202995.
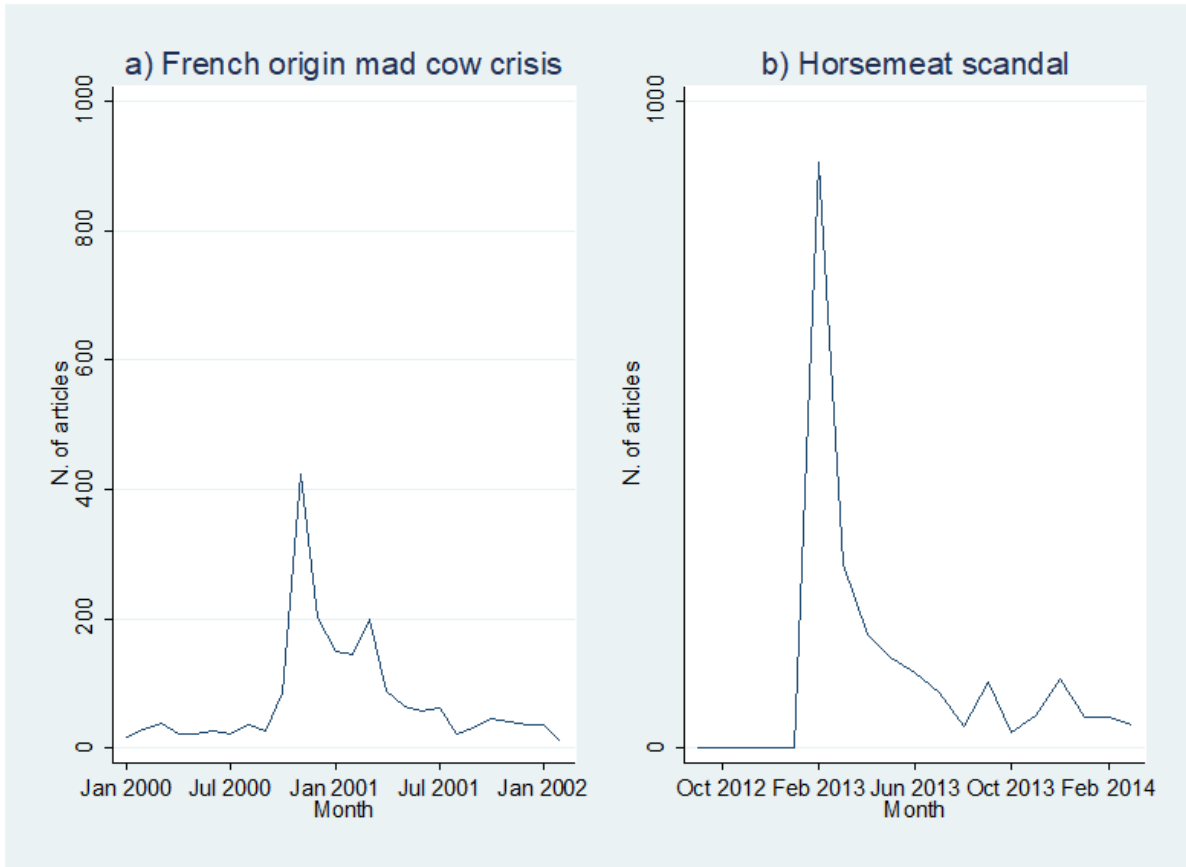
Figure 1: Monthly number of newspaper articles in the French written press mentioning the words (translated to French): a) "mad cow" and "meat", b)"horse meat" and "scandal" or synonyms of "scandal." Source of the data: Lexis-Nexis

or were not involved in the crisis, as many of them shared the same meat suppliers. Hence, consumers willing to react to the crisis likely had to avoid frozen dishes with ground meat as a whole and look for alternative product categories.

Both our application and the horse-meat scandal are product-harm crises in which it can be particularly costly for consumers to react, as it may be difficult to find alternative products with comparable product characteristics as the ones of the affected product. The lack of comparable alternatives is also likely to be relevant the more differentiated the products affected by the product-harm crises are. Example of industries in which products could be considered highly differentiated are highly branded industries where brands are a crucial component of consumer preferences, (e.g., due to consumer inertia as in Dubé et al., 2010).

Figure 2 compares the media coverage of other recent major product-harm crises in France, the country where the crisis we focus on occurred. Several of the major product-harm crises, in France and elsewhere, have their origins associated with industry-wide practices. For example, Freedman et al. (2012) link the 2007 toy recall to the industry-wide practice of licensing and branding the production of toys, in particular, to Chinese companies, rather direct manufacturing by the brand owner. In addition, the 2008-2009 "DMF sofa crisis" in the figure was due to the industry-wide practice in the sofa market of using a toxic antimold chemical (*dimethyl*
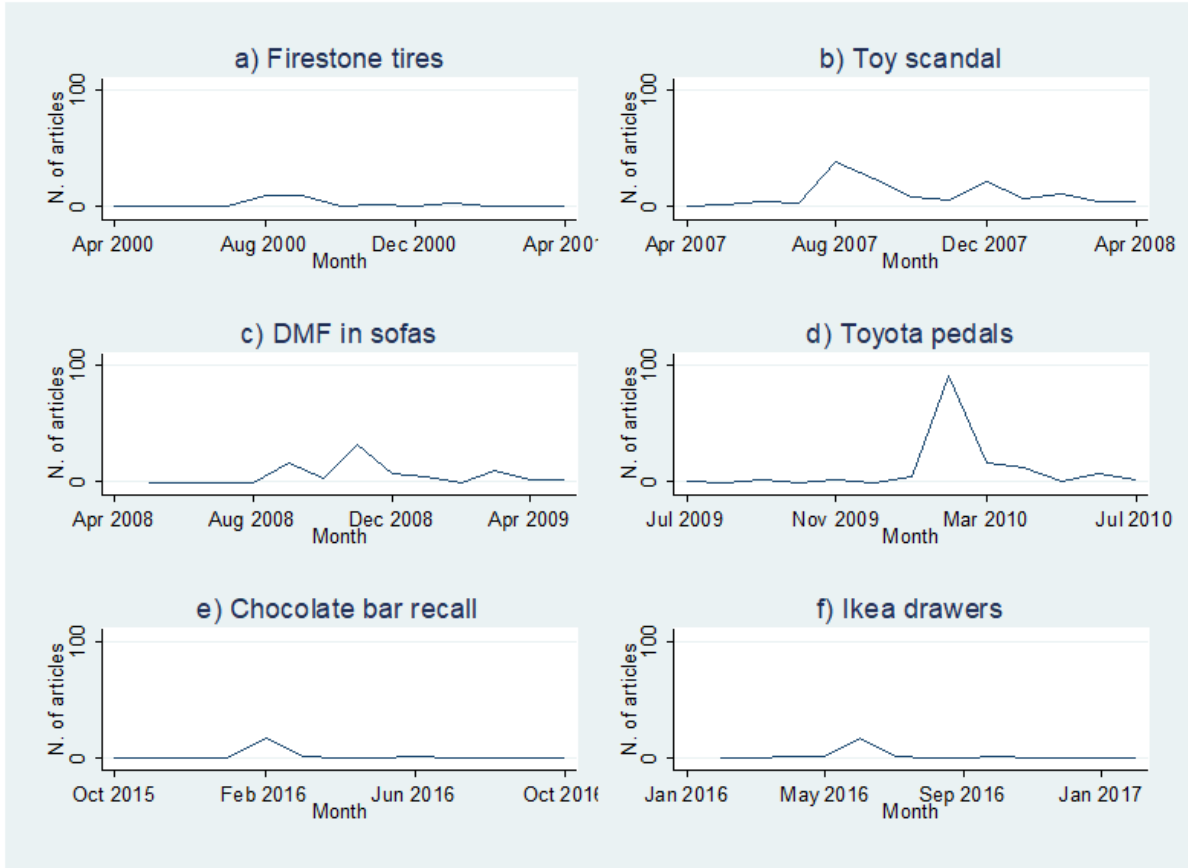
Figure 2: Monthly number of newspaper articles in the French written press mentioning the words (translated to French): (a) "Tires" and "Firestone" or "Bridgestone" or "Ford" (b) "toy" and "plummet" (very similar graph for "toy" and "plummet" and "Mattel" or "Fisher Price") (c) "sofa" and "Conforama" (d) "Toyota" and "brakes" (e) "Snickers" and "bars" and "red plastic" but excluding all Superbowl-related articles mentioning a commercial campaign in this sport's tournament that were not related to the product-harm crisis (f) "Ikea" and "dressers." Source of the data: Lexis-Nexis.

fumarate) to protect leather sofas. The figure also shows two other product-harm crises, the 2009-2010 Toyota pedal crisis and the 2000 Firestone crisis, that affected the automobile industry, which is characterized by industry-wide practices (e.g., outsourcing the production of distinct automobile parts, Novak and Stern, 2008) and can also be considered a highly branded industry.[12] Over the past decades, the automobile industry has experienced a large number of product recalls also affecting a large fraction of car manufacturers (Liu and Shankar, 2015).

2.1   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

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[12]The media coverage of the 2000 Firestone crisis is relatively low probably because it mostly affected the American market. Nevertheless, we include it because it occurred in the same year as the crisis we focus on, making it useful as a reference.

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).

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 nonfarmers 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).[13]

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 domestic. Three large supermarket chains (Auchan, Carrefour and Cora) sold meat that was subsequently found to be infected with BSE.[14] 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; and 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).

The 1996 UK origin crisis was a preceding major shock to consumers' perceptions four years prior to the episode we focus on. Therefore, there might have likely already been some variation in consumers' perceptions prior to November 2000. However, there are two reasons to think that the likely update of consumers' safety perception had stabilized by 1999, when our data begins. First, French beef aggregate consumption appears to be quite flat in the period between January 1998-November 2000 and between January 2002 and December 2003 (Lesdos-Cauhapé and Besson, 2007). Second, as shown in Figure 2a), the information shock in November 2000 was considerably large. Moreover, the shock informed about the risks of French beef consumption whereas the 1996 shock affected mostly beef with UK origin, which was banned in France between 1996 and 2002.

Overall, the mad cow disease epidemic caused the deaths of more than 200 people worldwide.

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[13]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.

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

After the UK, France was the country with the largest number of human victims (26 deaths).[15] 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.[16]

The left-hand side graph in 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 increase 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.

The second French mad cow crisis provides a useful 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, 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 comprises 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.[17] 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.[18] The two relevant macronutrients present in meat are proteins (g per 100 g) and lipids (g per 100 g), as fresh meat and fish contain no carbohydrates.[19] We

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[15]UK National CJD Research & Surveillance Unit

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

[17]We do not have display information in our dataset to test potential multiplier effects via display decisions; however, it seems unlikely that changes in display are a major source of the large consumer responses in the paper. An important limitation for short-term display changes in our particular application is that fresh meat and fish products need refrigeration. This reduces substantially the possibility of major display changes and makes it unlikely to have this products at the "end of the aisle."

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

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

also consider iron (mg per 100 g) because it is a key micronutrient present in meat, as noted in the literature on clinical nutrition (Alexander et al. (1994)).[20]

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, while the least consumed category is offal, followed by other meat. Beef and veal are the most expensive category, followed by other meat and pork. In terms of number of households that purchase the category, beef and veal are the category with the highest number of households purchasing each month (almost 2000 households on average). 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 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 meat 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 least expensive 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 least expensive source of lipids and proteins.

3.1 Quantities, market shares, and prices

In this section, we show reduced-form evidence of the effect of the safety crisis on quantities and volume market shares of the main categories of fresh meat we consider in this paper. We also investigate how prices of these categories vary after the safety event. Furthermore, we complement the analysis by studying the effect of the crisis on total household expenditure, which helps to shed light on how consumers rearranged their purchase baskets after the event.

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[20]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).
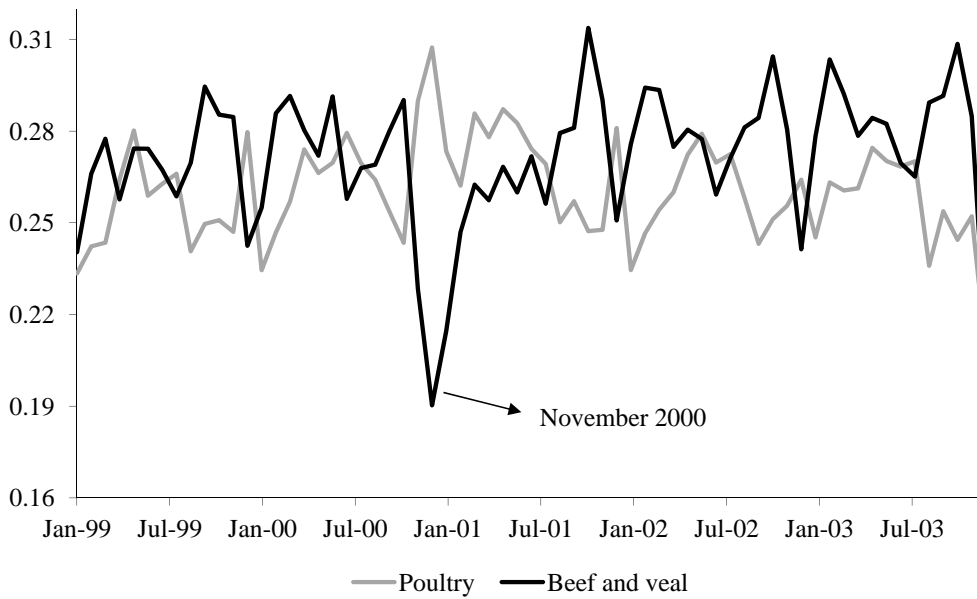
Figure 3: Monthly market shares, 1999-2003

Table 3 reports the effect of the mad cow event on the average price of beef and veal, poultry, and pork. 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, this variable 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 of analysis. Thus, by maintaining fixed the weight of each product, the fixed price index separates transaction prices movements from demand movements. To see more clearly how these indexes differ, suppose for example that the variable price index remains constant. This event could indicate that neither transaction prices nor demand have changed, but it could also be that transaction prices have decreased and demand has shifted to more expensive products (or that transaction prices have increased and demand has shifted to less expensive products) such that the net effect on average prices conditional on purchases is zero. To distinguish between these possible price and demand shifting effects, we should check the fixed price index. If the fixed price index also remains constant, this indicates that transaction prices have not varied. 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 nonsignificant for all products and for neither of the two price indexes, suggesting that the event had minimal impact on prices. This result is consistent with the agricultural statistical reports at the time (Lesdos-Cauhapé and Besson, 2007), which say that although

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intermediate prices varied during the crisis, the same was not true for consumer prices.

Table 4 shows the effect of the safety event on quantities and volume market shares of beef and veal (columns 1 and 2), poultry (columns 3 and 4), and pork (columns 5 and 6), as well as the effect of the crisis on overall total monthly purchased quantities of fresh meat and fish (last column). We observe a significant decline in total monthly quantities as well as in the volume market share of beef in the 3 months following October 2000. During this period, demand appears to have shifted from beef to poultry, as indicated by the positive and significant coefficients of the interaction of 1 to 3 months after the event and poultry on the quantity and market share regressions (third and fourth columns of Table 4). In contrast, the event had no significant effect on the monthly purchased quantities or market share of pork, which, as seen in Table 1, is the third largest consumed category. In Columns 3 and 4 of Table 4, there is an insignificant effect of the shock on pork quantities and market shares.

This predominant shift of demand from beef to poultry is illustrated in Figure 3. Considering that nutritional characteristics of poultry and beef differ considerably, it appears that households' unobserved taste for the different categories could have played a key role in the substitution pattern. In addition, consumers do not appear to be reacting to the mad cow event by substituting away from overall fresh meat and fish, as the event has no significant effect on monthly purchased quantities of overall fresh meat and fish as shown in the last column of Table 4. This result likely indicates that the main effects of the safety crisis were contained within the product categories we consider, not significantly affecting the demand of outside goods.[21]

4   The model

Our demand model is based on Dubois et al. (2014)'s approach. Consumers' utility depends both on product characteristics as in discrete-choice models and hedonic price models, and on quantity consumed of each product, as in demand models such as AIDS.[22] As a result of the preferences being defined both over the characteristics and the product space, the estimable equations include not only product observable characteristics (nutrients) but also household and product-specific intercepts which capture household unobserved taste. Therefore, with this model specification, we can not only test whether observed product characteristics affect consumers choices, but also measure the relevance of product observed characteristics relative to product-specific intercepts in determining products' purchases. Furthermore, the model generalizes the weak separability assumption common in traditional demand models by allowing for interactions between different products through their characteristics.

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[21]We further investigate the effect of the crisis on the demand for the outside good in Section 7. We find no evidence that households substantially switched to non-animal sources of iron or protein such as milk, eggs, cheeses, yogurt, lentils, spinach, chickpeas, and other beans.

[22]For discrete choice models see McFadden et al. (1973) and Berry et al. (2004); for hedonic price models, see for example Griliches (1961), Rosen (1974), Epple (1987); and for AIDS, see Deaton and Muellbauer (1980).

4.1 The setup

We consider N food products which are divided into J product categories, each category j having K_j subcategories. Household i has 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_{ikj} is the vector of quantities of food consumed letting each product n be labeled kj if it is the kth food item of food group j, 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 for each of the N products.

Note that without preferences for overall nutrition characteristics, z_i, the utility function would be weakly separable across categories, as is traditional in the demand literature. However, entering characteristics into the utility function breaks this weak separability by creating interaction between categories of products through their nutritional content. That is, as consumers obtain utility directly from nutrients regardless of their source, the marginal utility of consuming each product is affected by other products' consumption through the nutrient amounts already present is these other products.[23]

The utility obtained from products within the same category 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 $f_{ikj}(y_{ikj}) = \lambda_{ikj} y_{ikj}^{\theta_{ij}}$. With respect to product characteristics, we assume that $h_{ic} = e^{\beta_c z_{ic}}$. These imply that the utility function for product categories and product characteristics are Cobb-Douglas.

Note that 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 category will depend on individual consumer characteristics, but quantity will not vary with changes in consumer income though in the estimation we can control for income variation across consumers. Additionally, the model limits non-linear price effects.

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[23]For example, the marginal utility of beef can vary with the purchased amount of poultry due to the iron content present in the purchased quantity of poultry.

4.2 Household behavior

The problem of household i is to choose quantities of the N food products (plus the numeraire) to maximize utility subject to the budget constraint:

$$\max_{x_i,y_i} \prod_{j=1}^{J} \left(\sum_{k=1}^{K_j} \lambda_{ikj} y_{ikj}^{\theta_{ij}} \right)^{\mu_{ij}} exp\left(\sum_{c_1}^{C} \beta_c z_{ic} + \gamma_i x_i \right)$$

$$s.t. \sum_{j=1}^{J} \sum_{k=1}^{K_j} y_{ikj} p_{kj} + p_0 x_i \leqslant I_i$$

$$z_i = A' y_i$$

$$x_i, y_i \geqslant 0$$

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. A product is labeled k_j if it is the kth item of category j, where $k \in \{1, 2, ..., K_j\}$.

Hence, for each product y_{ikj} the first-order condition of the household' maximization problem is given by:

$$\mu_{ij} \frac{\theta_{ij} \lambda_{ikj} y_{ikj}^{\theta_{ij}}}{\sum_l \lambda_{ikl} y_{ikl}^{\theta_{ij}}} + \sum_c \beta_c a_{kjc} y_{ikj} = \gamma_i \frac{p_{kj}}{p_0} y_{ikj}$$

Then, summing the above first-order conditions over k for each given j yields:

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

The equation above has been aggregated at the product-category level and the left-hand side variable is the household's expenditure on food category j. There is conceptually no reason for working with a lower or higher level of aggregation. The level of aggregation chosen should be the most meaningful for the application at hand (Dubois et al., 2014).[24] The household's estimable purchase decision equation derives directly from this aggregated first-order condition, which allows us to directly introduce household heterogeneity in preferences.

5 Econometric Implementation

5.1 The estimable equation

The estimable equation comes from the first-order condition of the consumer problem (equation 2). As quantities and prices vary over time, we include a time subscript t to these variables. In addition, we let one of the product characteristics ($c = 1$) be unobserved such that the characteristics component of the FOC can be decomposed into an unobservable part and an

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[24]In the Implementation section below, we define what a product category is in our context and why we chose this level of aggregation.

observable part.[25] As discussed in the previous section, equation 2 is aggregated at the category level, which we consider to be the different meat groups (beef and veal, offal, poultry, pork, and other meat). This is the most meaningful level of aggregation in our setting because the safety shock affected entire categories of products rather than individual products separately. We can therefore introduce the shock to safety directly into the estimable equation through the unobserved characteristic.

We assume that $p_{0t}\frac{\mu_{ij}\theta_{ij}}{\gamma_i} + p_{0t}\frac{\beta_1}{\gamma_i}\sum_k a_{kj1}y_{ikjt}$ can be captured by a combination of fixed effects, which we specify as $\Psi_{ijt} + \delta_{ij} + \xi_t + \epsilon_{ijt}$. This combined fixed-effects term captures elements of preferences and the environment as detailed below.

The estimable equation is:

$$\omega_{ijt} = \sum_{c=2}^{C}\beta_c z_{ijct} + \Psi_{ijt} + \delta_{ij} + \xi_t + \epsilon_{ijt}, \tag{3}$$

where $\omega_{ijt} = \sum_k p_{ikjt}y_{ijt}$ 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.

Additionally, we assume that consumers' preferences for meat are also determined by the safety of each product category, which is also an unobservable product characteristic allowed to vary by consumer. Hence, a product-harm crisis that affects the safety perceptions of consumers could affect consumers' indirect utility from consuming the affected products. The term Ψ_{ijt} captures this effect of the safety shock. This term measures the per period variation in the preferences for category j that is due to the change in the safety perception following the product-harm crisis. Letting $t = \tau$ be the time period right after the event that triggers the safety crisis, we specify the effect of the shock as:[26]

$$\Psi_{ijt} = \begin{cases} \psi_{it} + \phi_{it} & \text{if } j \in \{\text{beef products}\} \text{ and } t \in \{\tau, ..., \tau + 17\} \\ \phi_{it} & \text{if } j \notin \{\text{beef products}\} \text{ and } t \in \{\tau, ..., \tau + 17\} \\ 0 & \text{if } t \notin \{\tau, ..., \tau + 17\}. \end{cases}$$

This component of the estimable equation is a key novelty of our work with respect to Dubois et al. (2014). To the best of our knowledge, we are the first to structurally estimate unobservable preferences for product safety using exogenous shocks to safety perception. We decompose Ψ_{ijt} into two effects. First, ψ_{it} measures the effect of the crisis on the preferences for

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[25]We decompose $\sum_c p_0 \frac{\beta_c}{\gamma_i}\sum_k a_{kjc}y_{ikj}$ in two terms:

$$\sum_c p_0 \frac{\beta_c}{\gamma_i}\sum_k a_{kjc}y_{ikjt} = p_0\frac{\beta_1}{\gamma_i}\sum_k a_{kj1}y_{ikjt} + \sum_{c=2}^{C} p_0 \frac{\beta_c}{\gamma_i}\sum_k a_{kjc}y_{ikjt},$$

where the first term in the right-hand side of the above expression is the unobserved characteristic, whereas the second term in the right-hand side comprises the observable characteristics of the product.

[26]As a robustness, in the Appendix, we use an alternative specification that takes advantage of the frequency of the French press' news stories on mad cow disease during the period of analysis. News stories allow relaxing the time discontinuity in Ψ_{ijt} by measuring the intensity of information on the product-harm crisis. We obtain very similar demand estimates

the directly affected product category. The effect is allowed to vary over time during the 18 time periods following the crisis. In addition, the safety shock is allowed to vary with the household, as different households may have different preferences with respect to safety or they may update their safety perceptions differently. This heterogeneous effect in the preferences for safety (or, more generally, in the responses to the safety shock) allows for effects of the safety shock on μ_{ij} and θ_{ij}. Second, ϕ_{it} captures the effect of the product-harm crisis on other product categories not directly involved in the product-harm crisis (that is, our model is sufficiently flexible to allow for spillover effects of product-harm crises on purchases of nonaffected product categories relative to the outside good). Finally, the overall effect is restricted to being equal to zero before the crisis and 18 time periods after the beginning of the crisis, that is, we assume there is no safety perception updating outside the 18 months following the crisis.

Preferences over meat categories are likely to vary across households. For example, some households might derive more utility from beef than do other households. The household-category effect δ_{ij} is meant to capture this. We call this term the idiosyncratic taste of the household for each meat category: it comprises all that gives consumer i utility from consuming category j that cannot be explained by nutritional characteristics or safety perception. The term ξ_t of the estimable equation captures common factors affecting the preferences for all meat and fish categories in each period. For example, fresh meat and fish could taste better during winter months.

The last term, ϵ_{ijt}, which is left as the econometric error term, includes other changes in the unobserved characteristics of the products and preference shocks that may vary per household and period and affect households' quantity choices. This implies that nutrients z_{ijct} are likely to be endogenous. Even if we allow for consumer-category fixed effects (δ_{ijt}) and period-category fixed effects (Ψ_{ijt} and ξ_t), there remain shocks, ϵ_{ijt}, at the household-category-time level that might be correlated with quantity choices and hence with nutrients in consumers' baskets, $z_{ijct} = \sum_k a_{kjc} y_{ikjt}$. We discuss how we account for the endogeneity of the nutrients below.

5.2 Instruments for nutritional content

Equation 3 has a potential endogeneity problem. To see this, note that the econometric error term ϵ_{ijt} in equation 3 comprises the random preference shocks and utility variation due to unobserved attributes (other than safety), as discussed above. Hence, this error term is likely correlated to quantity decisions y_{ijt}, and consequently, likely correlated with nutritional content, in which case z_{ijct} would be endogenous.

We address the potential endogeneity of z_{ijct} using instrumental variables. Valid instrumental variables in this context are variables that vary by household and period and are correlated with the nutritional content of consumers' choices, but uncorrelated with purchase quantity decisions. Therefore, variables that measure the changes in product availability due to exogenous reasons are valid instruments, as they have an impact on nutritional availability. Exogenous changes in the menu of products available affect the menu of nutrients that consumers encounter in the market each period. In particular, it affects the available nutritional content per gram in the market, which is correlated with the nutritional content of consumers' per period choices but

uncorrelated with their willingness to pay for the different products (conditional on household preference heterogeneity).

Note that market level variation in available products can be due to the entry or exit of products or changes in market structure, which in general can be correlated with consumers preferences in the market. Therefore, the change in available product nutritional attributes is a valid instrument for households' nutritional choices conditional on household preference heterogeneity. Our model includes a rich set of controls for household observed and unobserved heterogeneity. Specifically, it includes household-category specific intercepts, which capture unobserved heterogeneity in preferences for product categories, and household type-category-period specific safety shocks, which capture observable heterogeneity in safety preferences.[27] In addition, note that the different seasons or the safety crisis itself can also affect the availability of products in different markets. Thus, when we refer to exogenous changes in product availability, we mean exogenous also conditional on the season and the safety shock, which we explicitly control for in the estimated equations.

We construct the instruments in the following way. Although we do not directly observe product or nutrient availability at the store level, we can approximate it by listing all the products purchased per period in each store. In this way, we obtain the menu of nutritional attributes available per period and store conditional on overall households' purchases. To create the menu of nutrients available for each household each period, we assign each household to a reference group, depending on its geographical area and favorite retailer, defined as the most frequently visited retailer in a certain year (so household 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. For each list (i.e., reference group) and product category, we compute the average nutritional content (unweighted by quantities or frequency of purchase) across subproducts. Our instrumental variables are these averages per nutrient, meat category and reference group. Note that the averages vary per household, category, and period and are highly correlated with purchases' nutritional content. Our identifying assumption is that the variation in these unweighted averages of nutritional content, Ω_{ijct}, are uncorrelated with the econometric error term, conditional on the household-category fixed effects, δ_{ij}, the household-period-category fixed effects, Ψ_{ijt}, and the common factors, ξ_t. Hence,

$$E(\epsilon_{ijt}|\Omega_{ijct}, \delta_{ij}, \Psi_{ijt}, \xi_t) = 0 \tag{4}$$

Figure 4 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

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[27]As described previously, household types group households by region of residence and educational level of the main person responsible for shopping.

that the safety shock in October 2000 does not appear to have affected the variability of the instruments, implying there is no evidence that the shock affected nutritional availability in a systematic way.

We did a number of robustness exercises considering alternative definitions of the reference groups. Furthermore, we estimated the demand model in subsamples that excluded reference groups with less than 3 households, reference groups in which households made few purchases a year, etc., to check whether our results were being driven by just a few households or outlier purchase behavior. The main estimation results are robust to these changes.

6　Results

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

In the demand model and consistent with previous analysis in this paper, we consider 6 separate product categories: beef and veal, offal, poultry, pork, fish, and other meat. We show demand parameter estimation results for our preferred specification, in which the per-period safety shock is allowed to affect all product categories. We constrain the per-period safety shock to be the same across the categories not directly implicated in the safety crisis (that is, poultry, pork, fish, and other meat) so that the product-harm crisis has the same effect on all substitute categories. We allow the safety shock to be different between beef and veal, and offal. This approach accommodates the possibility that consumers saw offal as riskier than other beef and veal cuts, for example. Furthermore, the change in category safety perception is also allowed to differ across observably heterogeneous households. In our preferred specification, we consider households that differ in terms of region of residence and education level of the main person responsible for shopping. However, our main results also hold when we estimate alternative specifications that consider other dimensions of household observable heterogeneity, such as the presence of children in the household and the gender of the main person responsible for shopping. Note that heterogeneity in the way households adjust their safety perceptions following the safety event is the second source of heterogeneity in preferences that we allow for in the econometric exercise. The first source comprises household- and category-specific intercepts, which allow for consumers' heterogeneity in consumption utility that cannot be explained by nutritional composition or safety perceptions.

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 (Lesdos-Cauhapé and Besson, 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
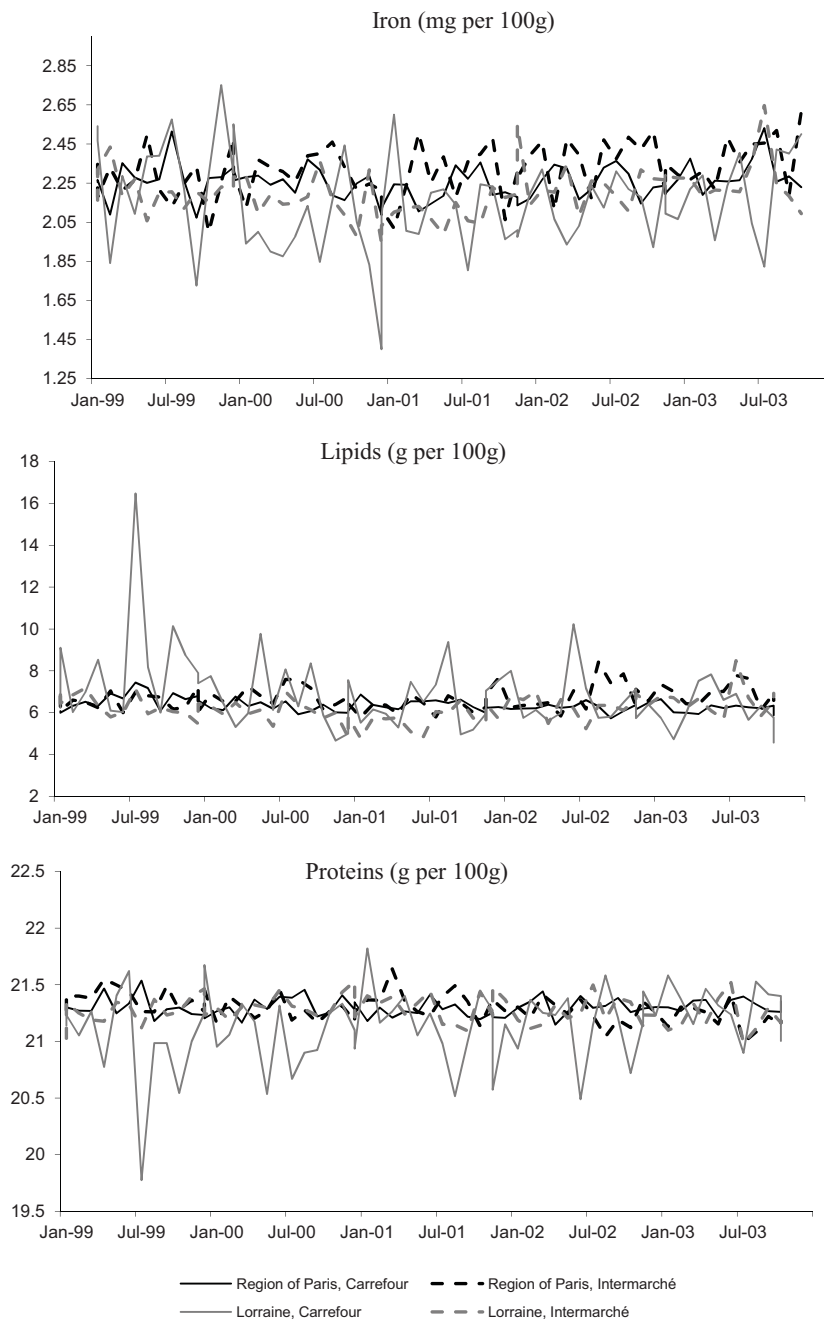
Figure 4: Monthly average nutrient content of beef and veal products available in the corresponding favorite store. The units of iron are in mg per 100 grams, and the units of lipids and proteins are in grams per 100 grams of meat, 1999-2003.

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 5 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 and third columns report estimates using instrumental variables. Column 2 shows parameter estimates for a specification in which the shocks to safety perception are the same across all households, whereas Column 3 shows estimates for a specification that allows safety perception adjustments to vary according to the education level of the household's person of reference (the main person responsible for shopping) and the region of residence. All equations include household-category fixed effects that measure the household-specific taste for each category.[28]

In all specifications, we observe a significant decline in the safety perception of beef and veal during the months right after the event, as can be inferred by the negative and significant shocks to these categories in the three months (4-week periods) right after the event. We also find significant evidence of some revival effects several months after the shock, as there are negative and significant shocks to beef and veal in some later months (specifically, periods 6 to 10 after the event in specification 2, and periods 7, 8 and 10 after the event in specification 3). In fact, the timing of these revivals appears to coincide with peaks in the number of newspaper articles observed in Figure 1, which arise due to subsequent newspaper stories covered in the media.[29]

With respect to nutritional characteristics, we find that they significantly affect consumers' preferences. The estimated coefficient for iron is positive and significant in all specifications, with a higher coefficient being obtained in the specifications with 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. Note that both the magnitude and the standard errors of the nutritional coefficients are very similar across the

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[28]Although not presented in the paper, we obtain very similar results when also including interactions between seasons and household-category fixed effects. We also obtain similar results when we allow the adjustment in safety perceptions to vary according to the presence of children in the households and household income level.

[29]In particular, the large significant coefficients for months 7 to 10 after the event observed in Table 5 coincide with the increase in media coverage after the death of French teenager Arnaud Eboli. The media had reported in the past about him having been diagnosed with a variant of Creutzfeldt-Jakob Disease, but his death, on April 24, 2001, and the resulting lawsuit and judicial investigation, were widely covered in the French media, e.g., Le Monde, July 28, 2001, "Arnaud Eboli est mort de la variante de la maladie de Creutzfeldt-Jakob. Les conclusions de deux rapports d'expertise." For the sake of clearer identification, our main analysis focuses on the estimated coefficients for the months closely following the beginning of the crisis. The arrival of new related information in later months is less likely to be exogenous and could be associated with potential confounding unobserved events. Nevertheless, for robustness, in the Appendix 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 threat in the period between January, 2000, and December, 2002. The number of news stories in a certain period serves as a proxy for the amount of public safety information on the affected product. Our main results also hold under this alternative approach

specification with homogenous safety perception shocks and the specification with heterogeneity in the safety perception shocks. 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 relative to daily recommended values and have relatively lower protein content variation across them in comparison to lipids and iron's variation (see Table 2). Furthermore, this negative coefficient could be related to the excessive protein intake in developed countries mentioned in Section 3. Regarding the coefficient for lipids, note that the nutrient parameters can also capture preference for the flavor of the nutrient, not only health concerns. Our empirical implementation 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 the leanest cuts).[30]

An advantage of the model is that it allows us to recover households' individual unobserved preferences per category, δ_{ij}. Table 6 reports the estimates of δ_{ij} averaged across households using the specification that allows for heterogeneous product safety shocks across different consumer types. The average household's favorite category is poultry, followed closely by beef. The estimated mean tastes for fish, pork and other meat are similar and considerably lower than the ones for beef and poultry. The least preferred category is offal. In the next section, we use these estimates calculated for the average household to conduct counterfactual exercises that quantify the importance of the taste for beef products on consumers' response to the safety crisis.

Note that our empirical approach assumes that we can separately capture time-variant and time-invariant components of consumers' preferences for the different meat categories, that is, (i) the time-invariant preferences for the different nutrients (i.e., the β's), (ii) the time-invariant unobserved taste for the meat category (the δ_i's), and (iii) the time-variant safety perception of consumers, which is affected by the shock. Hence, to check that the safety shock is not contaminating the estimates of the time-invariant preference parameters (i) and (ii), we re-estimate them on a subsample of the data that excludes the 18 months following the safety event. For these subsamples, the model parameters should be free of any potential effect of the crisis on consumer or supply behavior. We find estimated nutritional preference parameters and standard errors that are very close in magnitude to those estimated using the whole sample.[31]

6.2 Counterfactual exercises

Using the parameter estimates, we use our model to conduct counterfactual exercises that isolate the different drivers of the product-harm crisis' demand reaction. These counterfactual exercises

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[30]As mentioned before, we have checked the robustness of our results to our instrumental variables by estimating the model on a subsample that excludes reference groups that have less than 3 households and have less than 3 households who make a purchase each year. Estimation results for the subsample are identical to those of the complete sample with respect to significance and the sign of the estimated coefficients. In terms of absolute values of the point estimates, they are slightly higher once we drop the smaller reference groups, therefore reinforcing our results. Generally, the outcome of this robustness exercise indicates that our estimates are not driven by the behavior of a few individual households or purchases.

[31]The results are not provided here but are available upon request.

are not intended as policy counterfactuals, but they permit quantifying the determinants of consumer choices, as well as determining which alternative conditions could have exacerbated the drop in demand following the start of the crisis. All the counterfactual exercises below use model estimates from the most flexible specification we consider (instrumental variables and the per-period safety shocks that vary across observationally heterogeneous households).

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. Focusing on the average household, the exercise simulates average monthly purchased quantities in the four months after the event if there was no shocks to safety perceptions. To complement the exercise on the average household, we repeat the exercise at the household level to study heterogeneity in responses to the shock and how they relate to households' idiosyncratic unobserved taste for beef.

To obtain the quantity equation for the counterfactual exercises, we start by rewriting equation (3) as:

$$p_{jt} y_{ijt} = \sum_{c=2}^{C} \beta_c \sum_k a_{kjc} y_{ikjt} + \psi_{ijt} + \delta_{ij} + \xi_t$$

where we make use of $\omega_{ijt} = p_{jt} y_{ijt}$ and $z_{ijct} = \sum_k a_{kjc} y_{ikjt}$. Thus:

Then, isolating y_{ijt}, we obtain:

$$y_{ijt} = \left(\psi_{ijt} + \delta_{ij} + \xi_t \right) / \left(p_{ijt} - \sum_{c=2}^{C} \beta_c \sum_k a_{kjc} \right)$$

Taking averages and replacing parameters by their estimated values, we obtain the observed average monthly quantities purchased by the average household:

$$\bar{y}_j = \left(\hat{\psi}_j + \hat{\delta}_j + \hat{\xi} \right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_{k_t} a_{kjc} \right) \tag{5}$$

where:

$$\bar{y}_j \equiv \frac{1}{4N} \sum_{i=1}^{N} \sum_{t=\tau}^{4} y_{ijt},$$

$$\bar{p}_j \equiv \frac{1}{4N} \sum_{i=1}^{N} \sum_{t=\tau}^{4} p_{ijt};$$

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 four months after the event. The hat above a parameter indicates its estimated value. In particular, $\hat{\psi}_j$ is the safety shock for the average household averaged over the four months after the safety event, $\hat{\xi}$ is the estimated time fixed effect averaged over the four months after the safety event, and $\hat{\delta}_j$ is the estimated unobserved taste of the average household for category j.

To obtain the simulated average monthly purchased quantities in the four months after the

event by the average household if there were no shocks to their safety perception, we set $\hat{\psi}_j$ equal to zero for the four month after the shock. We denote these simulated quantities as $\bar{y}(No\ shock)_j$:

$$\bar{y}(No\ shock)_j = \left(\hat{\delta}_j + \hat{\xi}\right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_k a_{kjc}\right)$$

We compare $\bar{y}(No\ shock)_j$ and the actual purchased quantities $\bar{y}_j$ in (3). The percentage differences are calculated as:

$$\frac{\bar{y}(No\ shock)_j - \bar{y}_j}{\bar{y}(No\ shock)_j}. \tag{6}$$

To obtain 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:

$$\bar{p}(No\ shock)_j = \left(\sum_{c=1}^{C} \hat{\beta}_c z_{ijct} + \hat{\delta}_j + \hat{\xi}\right) / \bar{y}(No\ shock)_j.$$

Results of counterfactual 1

Table 7, first line, reports the results for this hypothetical scenario in which there is no shock to consumers' safety perception of beef after the event. The table shows in its first and second columns, respectively, the observed and simulated average monthly quantities purchased of beef after the event by the average household. Column 3 shows the percentage difference between the simulated and observed quantities, and the last column shows how much prices would have to vary to lead to the demand variation shown in the third column.

If the average household had not changed its belief about product safety, the average monthly purchase of beef in the four months after the event would have been 8% higher than the observed quantities after the event. The price of beef would have to be 15% higher than observed prices after the crisis to lead to the same drop in quantities as the safety shock. This result implies a price elasticity of demand of approximately -0.5.[32]

The above counterfactual is calculated for the average household; however, there is a substantial heterogeneity in consumers' responses to the safety shock. To study this heterogeneity, we calculate simulated quantities if there was no safety updating for each household and compare them to household-level observed quantities (i.e., we use an equation similar to equation but without averaging quantities across households). Figure 5 plots this percentage variation between simulated and observed quantities per household against households' unobserved tastes for beef. Whereas there is a large group of consumers in the upper tail of the taste distribution who do not respond to the safety shock, consumers with lower estimated taste for beef tend to considerably adjust downward their purchases of beef following the change in safety perception.

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[32]This elasticity for beef 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.
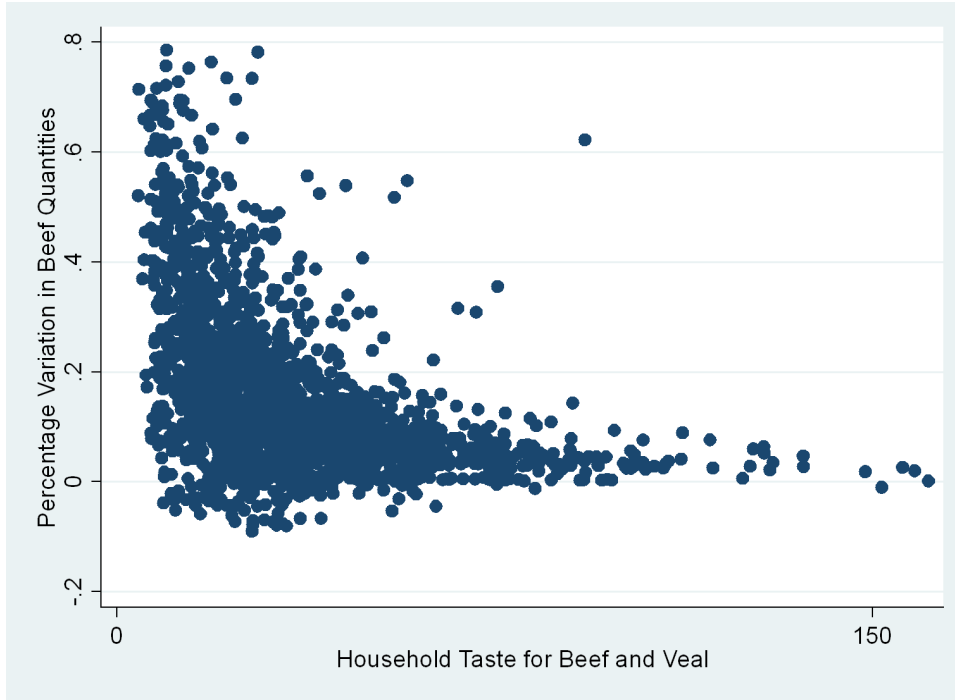
Figure 5: Relationship between households' taste for beef (estimated excluding the 18 months after the product-harm crisis) and their percentage variation in quantities purchased relative to simulated quantities without the product-harm crisis

6.2.2 Counterfactual 2: consumer reaction due to tastes

Counterfactual 2 sheds light on the role of consumers' idiosyncratic unobserved taste 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, he or she may resist reducing its consumption. 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 that consumers like less.

The counterfactual exercise uses the household-specific taste per category estimated in the demand model and reported in Table 6. We simulate monthly purchased quantities of beef in the four months after the mad cow crisis if the average household liked beef as much as they like pork, which is a category they have substantial lower taste for, although it is comparable to beef in terms of observable characteristics (see Table 2). 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 household are given by Equation 5. The simulated monthly purchased quantities of beef in the four months after the mad cow crisis if the average household liked beef as much as they like pork are given by

$$\bar{y}(Pork)_j = \left(\hat{\psi}_j + \hat{\delta}_{Pork} + \hat{\xi} \right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_{k_{t1}} a_{kjc} \right),$$

where j is beef.

The difference between the quantities in (5) and the simulated quantities $\bar{y}(Pork)_j$ is that in the latter the estimated unobservable taste for beef is replaced by $\hat{\delta}_{Pork}$, the estimated unobserved taste for pork. Hence, to calculate $\bar{y}(Pork)_j$ we use the average monthly quantities of beef that would have been purchased by the average household in the period following the event if the average household's taste for beef had been the same as their taste for pork.[33]

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

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

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 (6.2.2) but maintaining the actual estimated tastes for the beef category. That is, we calculate the following counterfactual price:

$$\bar{p}(Pork)_j = \left(\hat{\psi}_j + \sum_{c=1}^{C} \hat{\beta}_c z_{ijct} + \hat{\delta}_j + \hat{\xi} \right) / \bar{y}(Pork)_j.$$

Results for counterfactual 2

The second line of Table 7 reports the results for Counterfactual Exercise 2, in which we obtain simulated quantities by replacing households' taste for beef with the estimated taste for pork. Comparing observed (Column 1) and simulated (Column 2) quantities averaged over the four months after the crisis, we see that purchases of beef would have been 23% lower (Column 3) if the average household had liked beef as much as they like pork.

The last column of Table 7, second line, shows the importance of taste in limiting demand in monetary terms. It shows the price variation that would lead to the same decline in demand as a change in tastes. The price of beef after the crisis would have to be 31% higher than the observed prices after the crisis to lead to the same quantities as a change in tastes.

6.2.3 Counterfactual 3: consumer reaction due to nutritional characteristics

In this counterfactual exercise, we study the role of the nutritional characteristics in conditioning households' responses to the safety threat. We measure how consumers would have reacted to the product-harm crisis if beef had comparable nutritional characteristics to poultry. Note that although poultry is similar to beef in terms of the average household's estimated unobserved taste, it differs substantially from beef in terms of nutritional characteristics. Specifically, we

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[33]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 four months after the event and the (simulated) quantity that would have been purchased had there been a shock to safety perceptions affecting pork instead of beef.

answer the following question: how much beef would the average household have bought after the crisis if 1 kg of beef had the same nutritional characteristics, on average, as 1 kg of poultry.

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

$$\bar{y}(Poultry)_j = \left(\hat{\psi}_j + \hat{\xi} + \hat{\delta}_j \right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_k a_{kc}^{poultry} \right)$$

where j is beef and $a_{kc}^{poultry}$ is the average nutritional content of the poultry category.

To obtain a measure of the price variation necessary to lead to an equivalent demand response as the change in nutritional characteristic would, we calculate the following simulated prices:

$$\bar{p}(Poultry)_j = \left(\hat{\psi}_j^{avg} + \sum_{c=1}^{C} \hat{\beta}_c \sum_k a_{kc}^{Poultry} \bar{y}(Poultry)_j + \hat{\delta}_j + \hat{\xi} \right) / \bar{y}(Poultry)_j$$

Results for counterfactual 3

The third line of Table 7 shows the results of this counterfactual exercise. If beef had on average the same nutritional content as poultry, the average household would have purchased 19% less beef than actually observed 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 than poultry in terms of nutritional characteristics.[34] The last column of Table 7, third line, reports the price variation that would lead to the same demand response as in Column 3. Prices of beef would have to vary by 27% to lead to a similar demand drop in the purchases of beef.

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 four 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 minimally following the safety crisis. Hence, we expect to find limited difference between observed and expected quantities.

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

$$\bar{y}(equal\ price)_j = \left(\hat{\psi}_j + \hat{\delta}_j + \hat{\xi} \right) / \left(\bar{p}_j - \sum_{c=1}^{C} \hat{\beta}_c \sum_k a_{kjc} \right)$$

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[34]If beef had the same nutritional content as pork, on average, consumers would have reacted *less* to the crisis: they would have bought 18% *more* beef on average in the four months after the crisis. This result shows that if consumers cared only 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 can be inferred from the results of Counterfactual 2, it is likely that there is less substitution toward pork because pork is a considerably less preferred product category in terms of estimated unobserved taste.

The percentage differences are calculated as

$$\frac{\bar{y}(equal\ price)_j - \bar{y}_j}{\bar{y}(equal\ price)_j} \tag{7}$$

Results of counterfactual 4

The fourth line of Table 7 reports the 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 reiterate that changes in relative prices played a small role in explaining purchase responses to the crisis as simulated purchased quantities are very similar to observed quantities. This result was expected as prices varied minimally with the shock.

6.2.5 Implications for consumer welfare

The counterfactual exercises above permit quantifying consumers' costs after a product-harm crisis and to decompose these costs into how much is due to each of the different consumer demand drivers. These counterfactual exercises permit approximating the welfare effects of the crisis without having to perform a full fledged structural welfare calculation, which would require further assumptions on the utility parameters. In particular, the first counterfactual exercise approximates consumers' costs from being expose to a product that they perceive as less safe; and the second and third counterfactual exercises approximates consumers' costs from having to switch to a product that is not comparable in terms of unobservable and observable product characteristics, respectively. Consumers optimize by trading off these three difference sources of utility loss.

Counterfactual 2 shows that the easier it is for consumers to find a comparable product in terms of unobservable product characteristics, the less consumers accept being exposed to the safety shock. Similarly, Counterfactual 3 shows that the easier it is for consumers to find a comparable product in terms of observable product characteristics, the less consumers accept being exposed to the safety shock. We also calculate the price variation that would cause the same change in quantities as counterfactual 2 and 3. Although this price variation is not a direct measure of the change in consumer welfare, it gives an approximate measure of the monetary costs for consumers associated with switching from beef to a less preferred product category.

In addition to the above counterfactual exercises, we perform another exercise in order to further illustrate the relative importance of safety in comparison to the costs of giving up on other product characteristics. This last exercise consists of measuring how much higher would the safety shock have to be in order to induce the same sales response to the crisis as if the affected product had less desirable characteristics than beef. We focus on unobservable product characteristics (Counterfactual 2) because in our application it is more relevant than observable characteristics in determining consumers' decisions. Specifically, we ask the question: how much further would the average household have to adjust down their safety perception of beef after the event to generate the same drop in quantities as Counterfactual 2 (where we simulate the response to the crisis if consumers liked beef less). We find that the safety perception adjustment

of the average household would have to be 65% higher for the sales drop to be the same as the sales drop we would observe if consumers liked beef as little as they like pork.

7   Impact on basket of characteristics

In this section, we investigate the effects of the mad cow event on consumers' nutritional basket. Table 8 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 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 9, 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.[35] Excessive protein intake can have negative health consequences, including reduced energy, kidney disease, and osteoporosis, and can even cause some cancers.[36] 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 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 9 (Column 3).

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 9 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

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

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

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 at most 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 (Column 2 of Table 9). 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.

We also investigate the effect of the safety crisis on household monthly expenditure on and purchased quantities of protein-rich sources other than fresh meat and fish. The product categories we study are: milk, yogurt, cheese, and eggs. For conciseness we do not report estimated coefficients here, but we find no evidence that the mad cow event significantly affected either expenditures or purchased quantities of any of these product categories. These results are again consistent with consumers mainly switching across different fresh meat and fish categories as a response to the mad cow epidemic.

8   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 category, 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 also 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 main affected 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., if their idiosyncratic unobserved taste for it was as low as the one of a main substitute 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 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 are also considerably driven by consumers idiosyncratic tastes. Indeed, in our application, we find that consumers substitute mainly from beef 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. By taking into account consumers' preferences, firms can identify which product categories are prone to face stronger demand contractions following a crisis.

Finally, our results are relevant beyond product-harm crises. A key feature of these crises is that they affect a crucial product characteristic in consumers' valuation, product safety, which is commonly unobserved. But, in addition to product-harm crises, there are frequent crisis involving other types of information shocks that can severely affect product demand and firm value. Note that our analysis can be used more broadly to study information shocks affecting consumers' perception or valuation of an unobserved product characteristic affected by the crisis. For example, it can be used to analyze consumers' responses 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), their nutritional value (Ippolito and Mathios, 1990, Ippolito and Mathios, 1995, Dhar and Baylis, 2011) as well as to study demand responses to a negative shock on consumers' trust in a product or group of firms, such as, consumers' finding out that firms were lying about a product characteristic (e.g., as in the dieselgate scandal, Reynaert, 2015; or in cases of false health claims, Peltzman, 1981; and Rao and Wang, 2017).

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Tables

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	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

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

Table 2: Mean price of nutrients and mean nutrient content across meat cuts per meat category

Nutrient	Category	Mean Price (euros per 1mg)	Content (mg per 100g) mean	std dev
		Panel A		
Iron	Beef	0.34	2.67	0.25
	Veal	0.80	1.61	0.75
	Offal	0.21	4.51	1.83
	Poultry	0.48	3.10	2.68
	Pork	0.32	6.41	8.80
	Fish	2.32	1.16	1.32
	Other meat	0.41	5.41	8.96
		Panel B		
Lipids	Beef	0.18	7.69	4.66
	Veal	0.23	6.79	4.97
	Offal	0.13	7.35	4.21
	Poultry	0.15	7.96	6.02
	Pork	0.06	10.24	7.67
	Fish	0.77	3.21	3.38
	Other meat	0.17	8.70	4.72
		Panel C		
Proteins	Beef	0.04	21.26	0.99
	Veal	0.05	20.69	0.77
	Offal	0.04	20.23	4.20
	Poultry	0.03	25.81	3.50
	Pork	0.02	21.90	3.79
	Fish	0.05	19.58	3.51
	Other meat	0.05	23.69	6.05

Table 3: Price changes for beef, poultry, and pork after the event

	Beef Price Index		Poultry Price Index		Pork Price Index	
	Variable	Fixed	Variable	Fixed	Variable	Fixed
1 month after X category	0.1067	-0.3604	-1.1387	-0.9102	-0.9940	-1.3842
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
2 months after X category	-0.2210	-0.3465	-1.1487	-0.8822	-1.5593	-1.2831
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
3 months after X category	-0.2027	-0.2460	-1.2066	-0.9008	-1.8573	-1.8667
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
4 months after X category	-0.1342	-0.2566	-1.1316	-0.8300	-0.9670	-1.3158
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
5 months after X category	-0.1917	-0.3266	-1.2829	-0.7733	-0.8751	-1.1925
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
6 months after X category	-0.3187	-0.5468	-1.5715	-0.9327	-0.6112	-0.7947
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
7 months after X category	-0.2682	-0.6635	-1.5611	-1.0647	-0.7535	-0.9647
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
8 months after X category	-0.1575	-0.5891	-1.5243	-0.8190	-0.6893	-0.6234
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
9 months after X category	-0.0899	-0.5315	-1.5484	-0.8861	-0.7705	-0.7075
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
10 months after X category	-0.0906	-0.5700	-1.2536	-0.5091	-0.6951	-0.7986
	(0.4160)	(0.4541)	(3.1230)	(3.1860)	(3.1240)	(3.1819)
N	325	325	325	325	325	325
R^2	.9984341	.9980802	.9113748	.9051334	.9113139	.9053751
Category FE	Yes	Yes	Yes	Yes	Yes	Yes
Year, season, Christmas FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: 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 , poultry, or pork) over t months
after the events, $t = 1, ..., 10$.

Table 4: Changes in quantities and market shares of beef, poultry, and pork after the event

Variable	Beef Market Share	Beef Quantity	Offal Market Share	Offal Quantity	Poultry Market Share	Poultry Quantity	Pork Market Share	Pork Quantity
1 month after X category	-0.0739***	-836.7215***	-0.0374	-537.876	0.0425**	580.3614*	0.0099	139.6136
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
2 months after X category	-0.1101***	-1259.6914***	-0.043	-708.673	0.0686***	1000.5020***	-0.0361**	-429.2846
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
3 months after X category	-0.0638***	-717.5451**	-0.0386	-545.5444	0.0218	322.4282	0.0086	123.0844
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
4 months after X category	-0.0256	-317.8071	-0.0334	-381.8932	0.0086	91.0886	0.0057	75.6280
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
5 months after X category	-0.0194	-227.2253	-0.0359	-440.0742	0.0335*	403.3644	-0.0051	-47.2534
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
6 months after X category	-0.0253	-280.9612	-0.0304	-398.1964	0.0256	330.1286	-0.0262	-296.7140
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
7 months after X category	-0.0083	-226.8037	-0.0342	-242.3858	0.0329*	245.0032	-0.008	-90.7002
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
8 months after X category	-0.0311*	-428.4693	-0.037	-345.3154	0.0221	185.678	0.0218	246.0022
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
9 months after X category	-0.02	-419.3041	-0.0386	-188.5478	0.0144	-27.938	0.0262	254.4462
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
10 months after X category	-0.0249	-564.8589**	-0.0301	45.3278	0.0153	-132.0328	0.0196	156.4774
	(0.0167)	(287.0705)	(0.0856)	(1028.3018)	(0.018)	(298.6837)	(0.0182)	(304.0608)
N	390	390	390	390	390	390	390	390
r2	0.9946267	0.9886799	0.8579859	0.8542709	0.9937404	0.9877454	0.9935836	.9873002
Category FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year, season, Christmas FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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

Table 5: Utility parameter estimates

	(1) OLS	(2) IV	(3) IV and Heterogeneous shocks
Proteins	0.03***	-0.05***	-0.05***
	(0.00)	(0.01)	(0.01)
Lipids	-0.01***	0.03***	0.03***
	(0.00)	(0.01)	(0.01)
Iron	1.60**	2.47**	2.49**
	(0.67)	(1.02)	(1.03)
1 month after × beef	-0.32	-5.05***	-4.18
	(0.26)	(1.07)	(2.84)
2 months after × beef	-1.72***	-10.83***	-14.10***
	(0.28)	(1.74)	(3.22)
3 months after × beef	-0.87***	-4.28***	-7.00**
	(0.22)	(0.90)	(2.76)
4 months after× beef	-0.49**	-0.87	-3.08
	(0.23)	(0.68)	(2.48)
5 months after × beef	-0.11	-0.80	-5.73**
	(0.19)	(0.67)	(2.63)
6 months after × beef	-0.26	-1.72**	-4.06
	(0.24)	(0.71)	(2.57)
7 months after × beef	-0.54***	-1.34**	-4.38*
	(0.19)	(0.68)	(2.53)
8 months after × beef	-0.66**	-3.83***	-10.88***
	(0.29)	(0.87)	(2.92)
9 months after × beef	-0.76***	-3.33***	-2.44
	(0.22)	(0.80)	(2.54)
10 months after × beef	-1.07***	-4.32***	-7.29**
	(0.35)	(0.89)	(2.84)
N	423210	423210	419113
Household FE	Yes	Yes	Yes
Year, Season, Christmas FE	Yes	Yes	Yes
Weak IV test		10.94	10.89

Notes: All specifications include year, quarter and Christmas fixed effects.
The first column reports estimates of OLS with household-category
fixed effects; the second column, household FE and instrumental variables,
while the third column shows estimates of a model with instrumental
variables, household-category fixed effects, and heterogeneous
effects, and heterogeneous responses to the shock. The weak IV test is the
Cragg-Donald Wald F-statistic. "t months after X beef" is a dummy
variable indicating purchases of beef
'x' months after the event.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Average taste across households per category

Category	Mean taste	Std Dev
Beef and veal	31.20	20.53
Offal	11.69	5.79
Poultry	33.56	18.61
Pork	23.31	11.23
Fish	24.72	17.39
Other meat	22.74	10.53

Standard deviations of mean taste across households in parentheses

Table 7: Counterfactuals

Counterfactuals	observed quantities	simulated quantities	% variation in quantities	equivalent % variation in prices
Cf 1 - No shock	1944.63	2121.66	0.08	0.15
Cf 2 - Taste	1944.63	1583.00	-0.23	0.31
Cf 3 - Nutrition	1944.63	1638.23	-0.19	0.27
Cf 4 - Prices	1944.63	1946.53	0.00	-

Notes: Average consumer's simulated monthly purchased quantities in the three months after the event if: (Cf 1) there was no change in safety perceptions, (Cf 3) the average nutritional content per kg of beef and veal was the same as the taste for pork, the same as poultry, and (4) prices were the same as before the event. *Equivalent % variation in p* is the price variation that would lead to the same percentage variation in the demand as in column 4.

Table 8: 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, Season, Christmas 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 9: 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
Year, Season, Christmas FE	Yes	Yes	Yes
N	50255	50255	145866

Notes: 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.

Appendix

A. Effect of the crisis on the outside good

Table A1 shows the effect of the crisis on the outside good. More specifically, the changes that happened 1 up to 10 months after the event on (i) total quantities of food except alcoholic beverages and fresh meat (Column 1), (ii) total expenditure in food except for alcoholic beverages and fresh meat (Column 2), (iii) total food expenditures except for alcoholic beverages, but including fresh meat (Column 3), and (iv) the expenditure market share of fresh meat relative to total expenditure on food except alcoholic beverages (last column). All regressions include household fixed effects and, also, quarter, Christmas and year dummies.

The results indicate that there was a slight increase on food other than fresh meat expenditures in the first months following the event (around 7 euros, which represent an approximate 4% increase). Total expenditures with food increase by around 5 euros in the same period. In the second month following the crisis, both expenditures on food other than fresh meat and total food expenditure significantly increase by around 20 euros, which represent an approximate expenditure increase of 10%. From the third month after the crisis on, however, there seems to be no systematic increase on expenditures on food other than fresh meat (in the third period, there is no increase, followed by a significant decrease, then it goes up again, etc.). With respect to total food expenditures, it goes significantly down from the third month after the crisis onwards. With respect to the market share of fresh meat expenditures over total food expenditures, we see a slight significant decrease in the first two months after the crisis. In terms of percentages, there is a significant 4% decrease in the first month, and a significant 8% decrease in the second month. But this is followed by a 3% increase in the market share of fresh meat in the third month after the crisis. From the fourth month on, there is no relevant change in the market share of fresh meat expenditures. Hence, there seems to be a significant and relevant effect on nonmeat expenditures, but only in the 2 months following the event. Combined with the fact that we find little evidence of substitution towards other nonmeat sources of proteins and iron, the empirical evidence in Table A1 is consistent with an income effect in the 2 first months after the safety event, where consumers are spending less on fresh meat (because they are purchasing less beef, which is the most expensive fresh meat category), freeing up income to spend in other food categories. Nevertheless, the empirical evidence overall seems to indicate that most of consumers' reaction to the crisis happened within the fresh meat categories.

B. Media coverage as a measure of changes in safety perception

In this part of the Appendix, 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 events related to the product-harm crisis. The assumption here is that news stories provide new information on meat safety and that consumers not only pay attention to these stories but also update their beliefs regarding safety accordingly. 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

Table A1: Effect of the crisis on total quantities and total expenditure on food other than fresh meat

Variable	Quantity except meat	Expenditure except meat	Total expenditure	Meat Expenditure Market Share
1 months after	-2730.96	7.20***	5.43***	-0.01**
	(9575.59)	(1.63)	(1.72)	(0.00)
2 months after	5671.64	21.64***	21.16***	-0.02***
	(10590.31)	(1.80)	(1.91)	(0.00)
3 months after	-5625.51	2.47	-6.89***	0.01**
	(9557.49)	(1.62)	(1.72)	(0.00)
4 months after	-1500.78	-4.31***	-18.54***	-0.00
	(9502.36)	(1.61)	(1.71)	(0.00)
5 months after	-1819.95	-2.19	-17.96***	0.00
	(9484.83)	(1.61)	(1.71)	(0.00)
6 months after	-2715.97	7.93***	-6.65***	0.00**
	(9329.28)	(1.58)	(1.68)	(0.00)
7 months after	-5254.97	-7.17***	-26.31***	0.01***
	(9336.47)	(1.59)	(1.68)	(0.00)
8 months after	2665.44	7.59***	-13.30***	0.00
	(9266.31)	(1.57)	(1.67)	(0.00)
9 months after	1089.21	14.00***	-4.93***	-0.00**
	(9354.70)	(1.59)	(1.68)	(0.00)
10 months after	-4536.44	5.15***	-15.23***	0.00
	(9628.46)	(1.63)	(1.73)	(0.00)
N	145866	145866	145866	145866
R2	.0006138	.0769983	.0496946	.0251959
Household FE	Yes	Yes	Yes	Yes
Year, season, Christmas FE	Yes	Yes	Yes	Yes

Notes: Standard errors in parentheses;* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; quantities are in kg; Quantity and Expenditure except meat are total food quantity and expenditure on food (except alcoholic beverages), respectively, except for fresh meat; Meat Expenditure Market Share is the ratio between fresh meat expenditures and total expenditures; t months after is a dummy variable that indicates 't' months after the events, t=1,...,10.

information on the safety threat 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 an 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 ψ_{ijt}, is now captured by a continuous variable measuring the number of news stories in the French press that mention the mad cow threat 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 A2 reports estimation results. The first column reports OLS results with household-category fixed effects, the second column shows results from an IV estimation with household-category fixed effects, whereas the third column shows results from an IV estimation with household-category fixed effects and heterogeneous responses to the safety shock. We used the same instrumental variables as previously, which control for the availability of nutrients across markets and periods, as described in Section 5.

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 5. Focusing specifically on beef, the coefficient on news stories is higher in magnitude and significantly negative. This indicates that preferences for beef are negatively affected by the number of news stories, which we interpret here as a measure of changes in consumers' safety perception.

C. Heterogeneous effects

In Section 6, we recover the utility parameter estimates allowing for potential demographic heterogeneity in terms of geographical region and educational level (Column 3 Table 5). All our counterfactual exercises are based on the model estimates from this specification with safety shocks that vary across observationally heterogeneous households. Figure A1 reports the heterogenous shocks by education level of the main person responsible for shopping and the household's geographic region.

Table A2: Utility parameter estimates: Alternative specification of the safety crisis using newsstories

	(1) OLS	(2) IV	(3) IV and Heterogeneous shocks
Proteins	0.03***	-0.05***	-0.05***
	(0.00)	(0.01)	(0.01)
Lipides	-0.01***	0.03***	0.03**
	(0.00)	(0.01)	(0.01)
Iron	1.60***	2.54*	2.53*
	(0.03)	(1.00)	(1.00)
nb of newspapers articles	0.14***	0.48***	0.58*
	(0.02)	(0.09)	(0.24)
beef × nb of newspapers articles	-0.16***	-1.55***	-2.15***
	(0.03)	(0.26)	(0.56)
offal × nb of newspapers articles	-0.09	-1.16**	-1.34
			(.)
N	423210	423210	419113
Household FE	Yes	Yes	Yes
Year, Season, Christmas FE	Yes	Yes	Yes

Notes: All specifications include year, quarter and season fixed effects;
The first column reports estimates of OLS with household-category
fixed effects; the third column shows estimates of a model
with instrumental variables and household-category fixed effects;
the third column shows results for a model with instrumental variables and
household-category fixed effects and heterogeneous responses to the safety shock across
observably heterogeneous consumers.
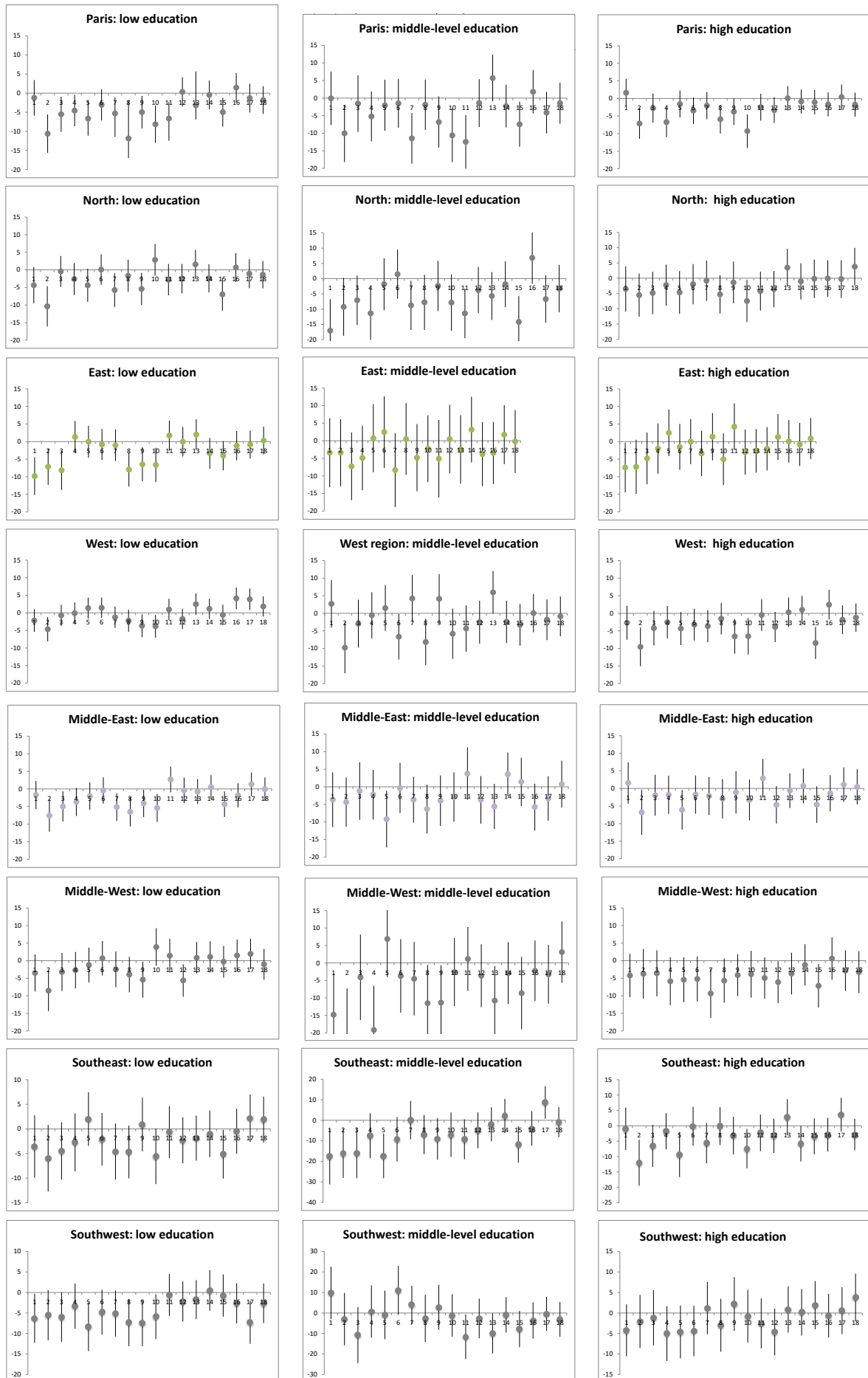* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure A1: Safety shock (marginal effects) across education levels and regions