Health Information and the Choice of Fish Species: An Experiment Measuring the Impact of Risk and Benefit Information

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Abstract

An experiment was conducted in France to evaluate the impact of health information on consumers' choice. Fish have positive and negative health attributes, and we focus on the fact that the amount of positive and negative attributes differ dramatically between two commonly consumed fish, tuna and sardines. Successive messages revealing risks (methylmercury) and benefits (omega-3s) of consuming fish, along with consumption recommendations, were delivered. Results show significant differences in reaction among participants depending on the order of information on risks and benefits. We combine the results of the experiment with a partial equilibrium model to determine the value of information. By taking into account adjustments of equilibrium prices for sardines and tuna, the value of health information computed in a partial equilibrium framework is shown to have significant positive value to consumers.

Keywords: experimental economics, fish consumption, health information, nutrition.

JEL Classification: C9, D8, I1.

1. Introduction

Public health communication programs aim at informing consumers about health benefits and risks associated with particular products or types of behavior. They affect consumers' choices by reducing uncertainty about the "true value" of goods, thereby improving the allocative efficiency of their consumption behavior. Nutrition information in public health often consists in advising changes between imperfect substitutes, as this is the case for the advice to choose vegetable oil (relatively rich in non-saturated fat) rather than butter (relatively rich in saturated fat) or to eat white meat rather than red meat. In other words, nutrition information aims at "forcing" substitution between different products.

This issue is particularly important for fish consumption since it involves a complex balance between benefits (with nutritional considerations) and risks (with toxicological considerations). Recently, several health agencies around the world issued messages regarding fish consumption. As there are large differences among fish species regarding their health-promoting content, knowledge about consumers' tendency to substitute different fish species for each other after revelation of information is essential for designing efficient health communication. As the US National Academies recently mentioned (National Academies, 2006, p.12) "Research is needed to develop and evaluate more effective communication tools for use when conveying the health benefits and risks of seafood consumption (…)"

The purpose of this paper is to evaluate the impact of health information on consumers' choice between a relatively "risky" type of fish (i.e., tuna) and a type of fish that is not only "less risky" but in addition offers health benefits (i.e., sardine). The risk and the benefit considered in this paper are, respectively, methylmercury and omega-3 fatty acids. For this, an experiment was conducted in France with women of childbearing age, since fish is particularly important during pregnancy. The women were endowed with a given quantity of “healthy” or “risky” fish and they were asked their willingness to exchange this endowment against a varying quantity of the other fish.[1] This experimental procedure allowed us to evaluate the substitution between products. Messages successively revealing risks and benefits were delivered, along with consumption recommendations.

First, results show significant differences of reaction among participants depending on the order of information on risks and benefits. When the risks are revealed before the benefits, only the risks information significantly modifies choice. Conversely, when benefits are revealed before the risks, both benefits and risks revelations significantly modify choices.

Second, we propose a new methodology that combines the results of this experiment with a partial equilibrium model for determining the value of information. Our experimental data are introduced into a calibrated model replicating observed data in a benchmark year. Simulating the impact of information on the market for sardines and tuna allows measuring the effects of demand variation on equilibrium prices. Surplus variations coming from the information revelation determine the value of information. As information entails price modifications via demand shifts, it is shown that the estimated value of information is positive but lower than a value of information estimated with constant prices**.** Consumers not belonging to the group at risk and not concerned by the information will also be affected by price variation.

The contributions of this paper are both empirical and methodological. First, from an empirical point of view, our paper differs from previous studies measuring the effect of

[1] This approach for measuring substitution is based on Masters and Sanogo (2002) and Sanogo and Masters (2002), focusing on a single endowment point (see also Binswanger, 1980). They, however, used only one type of product for the initial endowment. MacCrimmon and Toda (1969) were among the first in the experimental determination of indifference curves. Their experiments proceed by consecutive choices between two consumption bundles in order

information in experiments. For instance, Hayes et al. (1995), Fox et al. (2002), Noussair et al. (2002) or Wansink et al. (2004) combine positive and/or negative (or shorter and/or longer) information, for measuring the relative impact of these different options on the buyers' willingness to pay (WTP). Our results differ, since these authors revealed positive and negative messages on the *same* question issued by different actors in the information environment, while we consider different sequences in the revelation of a similar set of information. In our paper, there is no countervailing effect, and we show that the order of benefit and risk messages has implications regarding their efficacy in changing consumption behavior.

Second, our paper provides a new methodology to combine data from economic experiments with a partial market equilibrium calibrating the French market to obtain an estimate of the value of information (given by agents' surplus variations). In the calibrated model, the aggregate responses coming from the experiment are integrated by taking into the average values over the subjects. Whereas other papers, e.g., Huffman et al. (2003 and 2007) and Rousu et al. (2004, 2007), do not acknowledge the equilibrium price variations in response to health-related information, our paper completes the analysis by introducing equilibrium price variation. The results provide insights about distributional effects associated with health information over consumers "at risk" and concerned by the revealed information, and also consumers who are not directly concerned by the information but affected by resulting price modifications. This methodology provides new insights about the way to extrapolate results gained in the lab "to the world beyond" (see Levitt and List, 2007, p.1).

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to evaluate rates of substitution for varying endowments. This was considered too demanding on subjects when testing at the same time the successive revelation of information to consumers.

The paper continues with a brief presentation of risks and benefits of fish consumption. In the following sections, we describe the experiment and discuss the results. The paper concludes with a discussion of the implications for public health policy.

2. Fish consumption, health benefits/risks, and regulatory decisions

Safety and nutrition linked to fish consumption have become an increasing public health concern in recent years. In particular, methylmercury, an organic form of mercury, is a toxic compound that alters fetal brain development when there is significant prenatal exposure (EFSA, 2004). Children of women who consume large amounts of fish during pregnancy are particularly vulnerable to the adverse neurological effects of methylmercury (Budtz-Jorgensen et al., 2002). A high level of methylmercury is concentrated in long-lived, predatory fish, such as tuna, shark, and swordfish (Mahaffey et al., 2004).

The regulatory choice of how to manage this risk is complex since the nutrients in fish are also essential to the health of a developing fetus. More precisely, omega-3 polyunsaturated fatty acids, along with iodine, selenium, and phosphorus, confer benefits to the fetus such as infant cognition and improvement in cardiovascular health. According to the European Food Safety Agency (EFSA, 2005, p. 1), “Fatty fish is an important source of long chain n-3 polyunsaturated fatty acids (LC n-3 PUFA)…. There is evidence that fish consumption, especially of fatty fish (one to two servings a week), benefits the cardiovascular system and is suitable for secondary prevention in manifest coronary heart disease. There may also be benefits in fetal development, but an optimal intake has not been established.” In addition, there is still a lot of uncertainty and controversy about whether these benefits may outweigh the harm from mercury exposure.

Several countries have decided to broadcast specific advisories, including the US beginning in 2001, Canada in 2002, the UK in 2003, and Ireland, Australia, and New Zealand in 2004. The responsible health or food agencies of these countries have given an advisory that vulnerable groups (small children, pregnant women, and women of childbearing age) should consume fish while avoiding species at the high end of the food chain such as shark, swordfish, king mackerel, tilefish, and tuna because of high levels of mercury contamination (EFSA, 2004). The use of this advisory is of interest, as it mitigates the broad applicability of the general recommendation by nutrition and health experts to consume fish (in general without further qualification) twice or three times a week. This latter recommendation is motivated through the health benefit of a sufficient consumption of omega-3 fatty acids, a level that is considered to dramatically lower the risk of heart disease in adults.

Since 2001, the US has been active in disseminating the information for childbearing and pregnant women by using mass media or brochures distributed by gynecologists and obstetricians (EPA, 2004). The 2004 US advisory begins by explicitly mentioning the benefits of regular fish consumption because of the content of omega-3 polyunsaturated fatty acids.[2] The 2001 US advisory was found to have its intended effect, as pregnant women reduced their consumption of fish (Oken et al., 2003). However, the US advisory raised some criticisms by doctors (e.g., Drs. Hibbeln and Golding), who argued in favor of the large benefits of omega-3 fatty acids for fetuses (*The Economist,* 2006b). According to *The Economist* (2006a, p. 14), "the

[2] The advisory then stipulates that some fish species should be avoided, such as shark, swordfish, king mackerel, and tilefish. It also advises consumption of up to two average meals of fish per week that are "lower in mercury," such as shrimp, canned light tuna, salmon, pollock, and catfish, and limiting to only one meal per week the consumption of "albacore" (white) tuna because of a larger concentration of methylmercury compared to canned light tuna. Note that bluefin tuna (used for steak, sashimi, or sushi) is not mentioned in the US advisory despite an average content in methylmercury similar to the one for swordfish and king mackerel (banned by the advisory). According to Knecht (2006, p. P6), "Tuna, perhaps the most popular sushi fish, may contain high levels of mercury. 'A lot of people think sushi is a health food, but it isn't if you eat tuna sushi twice a week,' says Eli Saddler, a public health analyst with Gotmercury.org, an environmental advocacy group."

researchers note that American guidelines recommending that pregnant women should not eat fish because it may contain mercury have the perverse effect of cutting off those women (and their fetuses) from one of the best sources of omega-3s."

The content and the details of the advisories vary among countries because of idiosyncratic characteristics regarding the patterns of fish consumption and the type of fish commonly caught. There are substantial differences regarding both sequence of information revelation and species mentioned in warnings. All the messages explicitly mention the benefits of fish consumption, while they differ about the details linked to the benefits, since omega-3s and fatty fish rich in omega-3 are not always mentioned. The US and Australia/ New Zealand mention the benefits at the beginning of their advisories, while the other countries mention these benefits at the end of their advisories. Our experiment is useful to assess the effect of different sequences of revelation.

The French situation is interesting because no major diffusion of information has been decided upon yet.[3] Some warnings have been posted on the website of the Agence Française de Sécurité Sanitaire des Aliments, the French food safety agency (AFSSA, 2002 and 2004). However, despite few articles in the popular press (see, for instance, Miserey, 2003), no major broadcasting of information via obstetricians, maternity hospitals, or booklets was implemented by the sanitary authorities. This absence of national informative campaigns suggests that in France very few childbearing women are informed regarding the potential risk of methylmercury exposure. In contrast to the methylmercury issue, information on omega-3 fatty acids is

[3] One year after the experiment reported in this paper, the French food safety agency (AFSSA) issued a press release on methylmercury (AFSSA, 2006) that led to a few articles in the popular press. Tuna, in particular, is not mentioned in this press release. To the best of our knowledge, no major dissemination of information via obstetricians, maternity hospitals, or booklets is actually planned in France.

relatively widespread in France by mass media or advertising campaigns.[4]

This allows us to measure the effect in the laboratory under controlled circumstances. A similar procedure would not be possible in the US because of widespread broadcasts of the mercury message in 2002 and 2004. Because of the potential costs to society from inefficient regulation, the following experiment was designed to give evidence on which to base communication by taking into account the consumers' reaction regarding two different fish species. We particularly focus on different sequences of information.

3. The experiment

The previous discussion suggests the choice of some relevant variables for the experiment in order to fit real situations and thus help the public decision maker. We will successively detail the sample, the choice of products, the revealed information, and the experiment.

3.1 The sample

As pregnancy and breastfeeding status or being a young child are crucial indications for the risks linked to methylmercury, we focus on women of childbearing age, namely, women between 18 and 45 years old. We conducted the experiment in Dijon, the main city of Burgundy in France, in multiple sessions in January 2006. A sample of 115 women was randomly selected based on the quota method and is representative for age groups and socio-economic status for the population of the city. Women were contacted by phone. They were informed that they had to accept to eat

[4] For instance, the brand "Connétable" launched an advertising campaign about canned sardines (used in this experiment) and the benefit coming from omega-3s. From April to June 2005, this advertising was published in two national health magazines, five national women's magazines, six cooking magazines, and three TV magazines. See

both tuna and sardines during the experiment. Once they agreed to attend the session, they received a formal invitation letter and a reminder call a few hours before the experimental session. We used the INRA (Institut National de la Recherche Agronomique) sensory laboratory with kitchen facilities and computers for collecting subjects' responses. Each experimental session lasted one hour and included between 4 and 12 women.

3.2 The products

Tuna and sardines were selected as products (*i*) because they are frequently consumed in France and (*ii*) because their nutritional content is significantly different.

(*i*) This experiment focused on canned fish, known and consumed by almost all French consumers. Canned tuna and canned sardine are commonly consumed types of canned fish in France. The quantities consumed, however, are quite different, since 65% of canned fish consumed in France is tuna and 11% sardines (Ofimer, 2003). There is an asymmetry in consumption habits with an "a priori preference" for tuna, while the nutritional considerations revealed in the messages favor sardine consumption. As often the case, the nutrition information in this advisory aims at shifting consumption between imperfect substitutes.

The choice of the specific cans within tuna and sardines was mainly imposed by the available products on French grocery shelves at the end of 2005. As we are interested in estimating the substitution between two imperfect substitutes (namely, two types of canned fish), we aimed for similarity in the maximum number of elements for the experiment, namely, the same brand, sauce, weight, packaging, and almost the same price. This requirement allows us to

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http://www.connetable.com/ communication/index.asp (accessed February 2006).

isolate the substitution between the two different types of canned fish and the impact of information on consumers' choices.

We selected two cans of the French brand "Connétable" that satisfied numerous common criteria. Table 1 shows that the weights and the prices from the selected cans were very close.[5] The closeness in weight and price allows a direct comparison of the products by participants in the experiment. However, the price per kilogram was significantly larger than the average price in France, which suggests that we selected high-quality products (see table 1).

(*ii*) The other reason for the selection of tuna and sardines was the considerable difference in the contents of mercury and omega-3, as shown in table 2. Tuna contains high mercury and low omega-3 levels, whereas sardines contain high omega-3s (the highest levels in fish; see Sidhu 2003, table 5, p. 341) and low mercury levels. It should be noted, however, that data from different sources in the literature can show large variations because of the inherent variability in concentrations of samples as a function of species, age, and size, which are difficult to reflect in controlled sampling plans.[6] This explains the two figures proposed for omega-3 in canned tuna in table 2.

The contrasted contents in mercury and omega-3s have important consequences for information revealed during the experiment. We now turn to a description of the revealed messages.

[5] Details can be found on http://www.connetable.com/nos_produits/detail.asp?pid=35 (accessed February 2007) for tuna and http://www.connetable.com/nos_produits/detail.asp?pid=1 (accessed February 2007) for sardines. The only difference regarding the presentation was in the shape of the can. Note that for this experiment we used the 87g can for sardines that was replaced by the 115g can in January 2006.

[6] Canned tuna encompasses a variety of fish species, namely, the Skipjack, the Yellowfin, and the Albacore. According to EFSA (2005, table 8, p. 19) the average methylmercury content is 0.15 for the Skipjack, 0.3 for the Yellowfin, and 0.49 for the Albacore.

3.3 The revealed health information

During the experiment, different types of information about risk and benefits were communicated. We restricted our attention to one benefit, namely, omega-3 fatty acids, and one risk, namely, methylmercury.[7] The messages were inspired by elements coming from health agencies in different countries as described in the previous section.

While the complete information revealed to subjects is given in appendix A, it is possible to sum up the types of information delivered at different times as follows:

(1a) Information about the existence of omega-3 fatty acids with the ratio of omega-3s in sardines to omega-3s in tuna equal to 6.

(1b) Explanations about the health benefit coming from omega-3 fatty acids and recommendation regarding the weekly consumption of fish.

(2a) Information revealed about the existence of methylmercury with the ratio of methylmercury in tuna to methylmercury in sardines equal to 4.

(2b) Explanations about the health risk coming from methylmercury and recommendation for avoiding tuna.

We detailed ratios quantifying the relative content of nutrients and contaminants based on table 2, which is unusual compared to current public health advisories. This choice provides scientific credibility in our context and fits the restricted choice between only two types of fish in the experiment. We were conservative in the choice of the values of the ratio, which means that

[7] For simplicity, we abstract from communication on other risks of dioxins and PCBs or specific communication on other benefits coming from iodine or selenium in fish.

we took the values leading to the lowest differences in content between both types of fish.[8] In particular, we took the values given by Sidhu (2003) for omega-3s, namely, 0.5g and 3.3g in table 2.

For information (1) and (2), we separate the information regarding the nutrient and hazard content in fish ((1a) and (2a), respectively) from the description of the health effect and the consumption recommendation ((1b) and (2b), respectively). This split allows us to measure consumers' ability to interpret "raw" information ((1a) and (2a)) and to modify their purchasing decisions after recommendations ((1b) and (2b)). These recommendations were simplified in order to avoid confusion and the need to provide additional information about species. This explains why we mention the advisory to eat fish twice a week in (1b), while some recommendations mention the fatty fish (salmon, sardines, or mackerel), and why we maintain the advisory to avoid eating tuna in (2b), without differentiating among tuna species, such as the Albacore mentioned in the US advisory (EPA, 2004).

3.4 The experimental procedure

During the choice procedure, women were asked to choose between an endowment of six cans of Fish I and a variable number of cans of Fish II, varying from 1 to 12. We endowed participants with either six cans of tuna (groups A and B) or six cans of sardines (groups C and D). Different endowments are essential for obtaining complete information about substitution and for

[8] For the ratio of methylmercury, we did not consider the Albacore value (equal to 0.49 mg) that would be the specific level of the can used for this experiment. Our aim is to focus on tuna without detailing the species (which differs from the EPA, 2004). This choice is justified by the partial existence of labels mentioning species on tuna cans in France, so that communication on species would be shaky. Therefore, the mention of "canned light tuna" in advisories such as in the US (see EPA, 2004) is not possible in France.

determining welfare changes in section 5. We started with a relatively large number of cans (6) since cans of fish are a highly storable product (up to five years).

The experiment was divided into several stages.[9]

(1) Participating women read some general instructions and signed a form stipulating that they accept and will follow the rules of the experiment.

(2) They filled in a computer-assisted questionnaire on health and nutrition behavior and socio-demographic characteristics.

(3) They had one minute to examine cans of both tuna and sardines. Then the can price of the endowed Fish I was posted on the computer screen and participants were asked to give an estimation of the retail price of a can of Fish II.

(4) They had two minutes to taste both kinds of fish.

(5) The choice procedure was explained and the choice experiment was conducted for the following stages

    (i) without health information;

    (ii) after receiving message (1a) in groups A and C or (2a) in groups B and D;

    (iii) after receiving message (1b) in groups A and C or (2b) in groups B and D;

    (iv) after receiving message (2a) in groups A and C or (1a) in groups B and D;

    (v) after receiving message (2b) in groups A and C or (1b) in groups B and D.

(6) Participants replied to a short questionnaire on their understanding of information received and choices made.

(7) The experiment concluded by randomly selecting the products to be remitted to participants based on the selected choices. Participants also received €10 of indemnity and a brochure explaining the risks linked to methylmercury.

The choice procedure (5) was divided into five stages. In each stage, participants had to indicate their choices in 12 different situations. The 12 choice situations were presented on a single sheet of paper (see appendix B). The number of cans of Fish II varied from 1 to 12, each corresponding to one situation. For each line corresponding to one situation, participants had to choose either the six cans of Fish I or the indicated number of cans of Fish II. To avoid satiation effects, only one choice situation was selected randomly (at stage (7) of the experiment) among a total of 60 choices made during the five stages. Each woman then received the number of cans of Fish I or Fish II she preferred in this choice situation selected at random. This procedure is preference revealing, because each choice situation has a positive probability of being selected.

Before starting, the choice mechanism was explained and illustrated in a trial round.[10] After this warm-up round, women were asked in the first stage to make their definitive choices for the 12 situations without any health information. These choices represent an evaluation of preferences after product tasting and before revelation of health information.

For the following stages, information was successively revealed on the computer screen. Each message was posted for at least 30 seconds before participants could proceed to the following instructions. Each time, the speaker invited the women to carefully read the message

[9] No communication between subjects was allowed during the choice process.

[10] The explanation was read by the organizer before choices were made for all 12 situations. We recalled the price of Fish I and the value of endowment of six cans (namely, €9.90 for six cans of tuna or €10.14 for six cans of sardines). We included this training and explanatory phase to make the choice-revealing mechanism more transparent. From these 12 training choices, we simulated some random choices among the 12 choices as an example to facilitate their understanding that each choice could determine what they would actually take home. Participants were allowed to ask questions.

before making new choices regarding the substitution between Fish I and Fish II. When new information was provided, the previous message was maintained in grey, while the new message appeared in blue. We conducted the experiment in four treatments, varying the fish species in the initial endowment (tuna or sardine) and changing the order of information about the risk of methylmercury (2a) and (2b) before the information about benefits of omega-3 fatty acids (1a) and (1b) and vice versa. Table 3 describes the experimental design and the number of attendants.

3.5 The interpretation of results

The idea developed by Binswanger (1980) and Masters and Sanogo (2002) is to use respondents' choices to infer their relative preference and WTP. This procedure is simpler than the Vickrey (1961) auction mechanism and it focuses on the relative value of a good relative to another product. Based on product substitution, this methodology is particularly tailored to our empirical question searching for details regarding the consumption of fish species. The number of cans of Fish II at which the consumer switches from six cans of Fish I to Fish II can be interpreted as the point at which the consumer reveals indifference (Sanogo and Masters, 2002, p. 257). In contrast to their approach that estimates WTP for almost perfect substitutes that differ only in their information content, we are interested in estimating the substitution between two imperfect substitutes because of nutrition considerations. Tuna and sardines differ not only in the risk/benefit dimension but also in other preference dimensions such as taste.

In this experiment, the consumer owns a given quantity of $\overline{q}_I = 6$ cans of fish I.[11] The experiment provides the selected quantities of Fish II, q_{II}. The consumer being indifferent between the two product bundles is denoted as

$$\overline{q}_I \sim q_{II}. \tag{1}$$

Based on the 12 observed choices at stage *j* with $j \in \{i, ii, \ldots, v\}$ (see section 3.4), the experiment allows us to isolate the quantity $\tilde{q}_{II}^{j}$ for which $\tilde{q}_{II}^{j} - 1 \prec \overline{q}_I^{j}$ and $\tilde{q}_{II}^{j} \succ \overline{q}_I^{j}$. We use this quantity at which subjects switch to define the switching ratio. The implicit switching ratio (SWR) for the good *II* in terms of the price of good *I* is

$$SWR_{II}{}^{j} = \frac{6}{\widetilde{q_{II}}^{j}}, \tag{2}$$

where $j \in \{i, \ldots, v\}$ denotes the five stages of choices under the different contexts of information (see the previous section 3.4).

Equation (2) is an estimation of preferences for good II (relative to good I). An increasing switching ratio $SWR_{II}{}^{j}$ (namely decreasing $\widetilde{q_{II}}^{j}$) during the experiment implies increasing preference for good II relative to good I, since a lower number of cans of good II is preferred to 6 cans of good I.

This framework can be adapted to reveal relative WTP. As the observed can price $\hat{p}_I$ of the endowed Fish I was posted on the computer screen before subject choices (see point (3) in previous subsection 3.4), it is possible to determine the unknown WTP denoted by wtp_{II}^{j} for fish

[11] As the weight of the cans are almost similar (see table 1), we abstract from the slight quantity difference.

II at stage *j*. From the previous paragraph, it follows that $wtp_{II}^{j}\left(\tilde{q}_{II}^{j}-1\right)<\hat{p}_{I}\overline{q}_{I}^{j}$ and $wtp_{II}^{j}.\tilde{q}_{II}^{j}\geq\hat{p}_{I}\overline{q}_{I}^{j}$. Rewriting the previous inequalities leads to[12]

$$\frac{6}{\tilde{q}_{II}^{j}}\leq\frac{wtp_{II}^{j}}{\hat{p}_{I}}<\frac{6}{\tilde{q}_{II}^{j}-1}. \tag{3}$$

Equation (3) implies that equation (2) approximates the ratio between the WTP for good II, $p_{II}{}^{j}$, and the WTP for good I, p_{I}, with

$$SWR_{II}^{j}\approx\frac{wtp_{II}^{j}}{\hat{p}_{I}}. \tag{4}$$

In other words, the switching ratio approximates the WTP of good II relative to the revealed market price of good I. This relative WTP is an average WTP, as we do not derive it for a marginal change in demand but for a discrete change in demand. Because of this and under the assumption of WTP to be decreasing with demand, one would expect that WTP at the margin is overestimated.[13]

If during the experiment every $q_{II}\in\{1,...,12\}$ only satisfies $q_{II}^{j}\succ\overline{q}_{I}^{j}$ (only cans of Fish II were selected for situations 1 to 12), we arbitrarily determined a value $\tilde{q}_{II}^{j}=1$. If during the

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[12] Note that, although at stage (3) of the experiment, we announced the actual market price of fish I, $\hat{p}_I$, and the value of their endowment, this step is not necessary for the results that follow. Instead of using $\hat{p}_I$ as in Masters and Sanogo (2002), it would be possible to use the unknown WTP for fish I, wtp_I. In stage (3), subjects also gave their estimation of the retail price of a can of Fish II. The estimates are on average very close to the observed retail prices detailed in table 1. Indeed, the average price for sardines estimated by groups A and B was 1.55€ (retail price 1.69€). The average price for tuna estimated by groups C and D was 1.59€ (retail price 1.66€).

[13] This type of average WTP evaluation is difficult to avoid in experimental economics or contingent choice studies. The size of the good is often changed in discrete steps of significant size to make sure that sufficient stakes are involved for the participants to go through the effort of the valuation exercise. Hence, properly speaking we are evaluating average WTP for the number of cans involved. To avoid this issue in this choice experimental framework it would be necessary to recur to MacCrimmon and Toda's (1969) methodology, which seemed too demanding on the subjects when information is revealed during the choice procedure (see footnote 1).

experiment no $\widetilde{q_{II}}^{\,j} \in \{1,...,12\}$ is observed for a respondent, we arbitrarily determined a value $\widetilde{q_{II}}^{\,j}$ =13. Based on this convention, $SWR_{II}^{j} \in [6/13, 6]$. Extreme points (namely, boundary choices $\widetilde{q_{II}}^{\,j}$ =1 or $\widetilde{q_{II}}^{\,j}$ =13) may lead to an under- or overestimation of the substitution between products. Despite this limitation, the methodology is useful for providing information regarding the consumers' substitution for fish that varies in nutrient and hazard components and the effect of information on relative preferences.

4. Experimental results

From respondents' choices, we computed the switching ratio $SWR_{II}{}^{j}$ for products at the different information stages regarding the revelation of information. Based on equation (2), figure 1 presents the average switching ratio $SWR_{II}{}^{j}$ by group for all respondents at the successive stages of information revelation (on the X axis). Recall that in groups A and B (C and D), consumers were initially endowed with six cans of tuna (sardines).

The first bar for every group in figure 1 indicates participants' $SWR_{II}{}^{i}$ after tasting both products and without health information (initial stage *i*). The $SWR_{II}{}^{i}$ for sardines by groups A and B is lower than the $SWR_{II}{}^{i}$ for tuna by groups C and D. This means that women attending the experimental sessions had a higher initial preference for tuna, which is consistent with product shares observed in the French market. Table 4 also shows that there is a stronger preference for tuna than for sardines. Many more people constantly choose tuna, no matter how large the number of cans of sardines they can receive (10 subjects in group A and B combined), or how small the number of cans of tuna they receive (4 subjects in Group C and D).

The revelation of information leads to several interesting results in figure 1. First, the information leads to an increase in SWR for groups A and B and a decrease in SWR for groups C and D, a result that implies that health information matters to the women. We tested for the significance of these differences using the Wilcoxon test for paired samples. Those differences that were significant at the 5% level are identified in figure 1 using a Δ* at the change of information. We repeated the same tests while excluding the extreme observations defined by $q_{II} = 1$ and $q_{II} = 13$ (see footnotes *a* and *b* in Figure 1).

The overall effect of the information linked to the complete revelation of the four consecutive messages (the difference between the fifth bar and the first bar in each figure) has a larger effect on the variation of SWR for sardines than on the variation of SWR for tuna. Indeed the average SWR for the sardines increases by 1.01 in group A (the difference between the fifth bar and the first bar), while the average SWR for tuna decreases from 0.68 in group C (the order of information was the same for both groups). Moreover, the SWR for the sardines increases by 0.54 in group B, while the SWR for tuna decreases from 0.40 in group D. These numbers indicate that the effect of information is not symmetric in the initial endowment.[14] The change in SWR for sardines is larger, namely when consumers are initially endowed with tuna.[15]

Second, the order (equivalent to some extent to the emphasis) of the messages is crucial. It turns out that the information about mercury (message 2a) leads to a significant change in

[14] The literature showed that an endowment effect exists if consumers prefer to keep their endowed good (Kahneman et al., 1990) and if goods are not close substitutes (Haneman, 1991, and Shogren et al., 1994).
[15] We conducted a 2-Sided Mann-Whitney-U-Test on the hypothesis that SWR of groups A and B and groups C and D come from the same distribution. It yields a test statistic of 589.500 (p-value 0.000), which means that the H_0 of both samples coming from the same distribution is rejected at the 1% significance level. For comparing groups A and B and groups C and D, we used the switching ratio defined according to equation (2). The switching-point quantities are, respectively, $SWR_{sardines} \in [6/13, 6]$ for groups A and B and $\widetilde{SWR}_{sardines} = 1/SWR_{tuna}$ with $\widetilde{SWR}_{sardines} \in [1/6, 13/6]$ for groups C and D. Only the points between 6/13 and 13/6 were considered for computing

SWR whatever the order. If we consider the difference between the fifth bar and the first bar, the SWR increase for sardines is larger by 0.47 in group A compared to group B and the SWR decrease for tuna is larger by 0.28 in group C compared to group D. In particular, if messages (2a) and (2b) on methylmercury precede messages (1a) and (1b) on omega-3s (for groups B and D), then the major shift in the SWR is coming from the information on methylmercury. In other words, the information on omega-3s does no longer cause subsequent change in substitution.

Information on omega-3s only changed SWR significantly if it came before information about mercury (for groups A and C). If messages (1a) and (1b) on omega-3s precede messages (2a) and (2b) on methylmercury, the information on omega-3s does have an effect on the SWR. Nevertheless, the information about methylmercury still has a larger impact on the SWR than the information about omega-3s (see group A). Including extreme observations (with $q_{II} = 1$ and $q_{II} = 13$) matters to explain significance of additional information on the SWR shifts denoted by Δ^{*a} in groups A and C. Indeed, extreme points are mainly coming from subjects initially not interested in sardines with $\widetilde{q_{Sard}}^{i} = 13$ inside group A and $\widetilde{q_{tuna}}^{i} = 1$ inside group C at stage *i*.[16]

Third, the explanation of the health effect and the corresponding recommendation at the second round of information and revealed in messages (1b) or (2b) (third bar in figure 1) matters since the SWR shifts compared to the first rounds of information in messages (1a) and (2a)

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the 2-Sided Mann-Whitney-U-Test. This led us to consider 45 observations for groups A and B and 56 observations for groups C and D.

[16] The difference between the average SWR after and before information (equivalent of fifth bar and the first-bar in figure 1) for the entire subgroup with $\widetilde{q_{Sard}}^{i} = 13$ or $\widetilde{q_{tuna}}^{i} = 1$ is larger in absolute value than the difference for the other subjects with $2 \leq \widetilde{q_{II}}^{i} \leq 12$. 60% of subjects initially not interested by sardines with $\widetilde{q_{Sard}}^{i} = 13$ inside groups A and B switched towards sardines after the revelation of information with $\widetilde{q_{Sard}}^{j} \leq 12$ for $j \neq i$. 45% of

detailing only the relative content in the nutrient/contaminant (the second bar) matter in groups A, C and D (see note *b* in figure 1). The effect is only significant the end of the experiment (stage (*v*), fifth bar) in group A. This result suggests that information satiation is easily achieved (see also Wansink et al., 2004). This result is also apparent in table 4, which shows the number of subjects who change their switching ratio after receiving a message.

Since the information significantly influences the SWR, we now turn to the impact of information on the agents' surplus for determining the value of information.

5. Welfare analysis for estimating the value of information

We now turn to a welfare analysis estimating the value of information from switching ratios defined in equation (2) and presented in figure 1. For simplicity, we only consider the information impact after the complete revelation of the messages at the last stage $j=v$, which allows us to pool groups A and B and groups C and D, respectively.

Following Foster and Just (1989) and Teisl et al. (2001), information is welfare enhancing if consumers change their consumption behavior. Conversely, if consumers' purchases do not change, information has no value. Thus, the value of information is estimated by the difference in agents' surplus between the situation with a complete revelation of health information at stage $j=v$ and the situation without health information at $j=i$. As we focus on choices between imperfect substitutes, the surplus comparison needs to take into account imperfect substitution between the two goods. In this context, a consumer may continue to

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subjects initially not interested by sardines with $\widetilde{q_{tuna}}^{i} = 1$ inside groups C and D switched towards sardines after the revelation of information with $\widetilde{q_{tuna}}^{j} \geq 2$ for $j \neq i$.

purchase both tuna and sardines after the revelation of information, even if she reduces her tuna purchases and increases her sardine purchases. This point differs from the methodology used by Huffman et al. (2003 and 2007) and Rousu et al. (2004 and 2007) since they assume that a consumer purchases only one type of product.

One way to consider imperfect substitution consists in combining switching ratios coming from the experiment with a calibrated partial equilibrium model measuring imperfect substitution between sardines and tuna and being able to replicate prices and quantities in the French market. This calibration allows us to evaluate the market price modification and shifts in agents' surplus that would arise in response to the information revelation.

5.1. The model

The switching ratio $SWR_{II}{}^{j}$ for fish II relatively to fish I at stage *j* is an indicator of preferences for fish II. By using (4), a relative measure of the impact of information on preferences for product II is given by

$$\delta_{II} = \frac{SWR_{II}{}^{v} - SWR_{II}{}^{i}}{SWR_{II}{}^{i}} \simeq \frac{wtp_{II}^{v} - wtp_{II}^{i}}{wtp_{II}^{i}}, \qquad (5)$$

where the complete revelation of health information is defined by stage $j=v$ and the situation without health information is defined by $j=i$.[17] Thus, δ_{II} represent the relative change in the per-unit willingness to pay for fish II coming from health information. This measure isolates the effect of health information, abstracted from any quality/quantity effects linked to the products I and II. A positive value of δ_{II} means an increase in the willingness to pay for fish II. The experiment with groups A and B gives us relative changes in the willingness to pay for sardines, δ_S, and the experiment with group C and D gives us the relative changes in the willingness to pay for tuna, δ_T. These values may be used in the following model.

Demand and supply are considered as linear (as in Lichtenberg et al. (1998) and Sobolevsky et al. (2005)). We combined Spence's (1976) quasilinear utility function with the approach by Polinsky and Rogerson (1983) for the treatment of the health information in a demand function. Spence's (1976) specification of the utility function of imperfect substitutes is consistent with the assumption of separability of the two goods in question from all other goods that drives our experiment (see section 3.5).[18] The utility function of a consumer *k={1,…,K}* concerned by the revealed information is:

$$U_k(x_{tk}, x_{sk}, v_k) = \alpha_t x_{tk} - \beta_t x_{tk}^2/2 + \alpha_s x_{sk} - \beta_s x_{sk}^2/2 - \gamma x_{tk} x_{sk} + I_j(-r_{tk} x_{tk} + h_{sk} x_{sk}) + w_k\,, \quad (6)$$

subject to $x_{tk}, x_{tk} \geq 0$ and where w_k is the numeraire good. $\alpha_t x_{tk} - \beta_t x_{tk}^2/2$ ($\alpha_s x_{sk} - \beta_s x_{sk}^2/2$) is the immediate satisfaction from consuming a quantity x_{tk} of tuna (x_{sk} of sardines). The parameter γ describes the degree of substituability between the two products with $\gamma < Min[\beta_t, \beta_s]$ for concavity. The parameter I_j represents the information context. At stage *j=i* no information has been revealed and I_i=0. I_v=1 means that the subject received complete information at stage *j=v*. The perceived risk (perceived health benefit) for consumer *k* associated with the consumption of tuna (sardine) is denoted by $-r_{tk} x_{tk}$ ($h_{sk} x_{sk}$). Thus, the utility weight per-unit risk is $-r_{tk}$ and per-unit health benefit h_{sk}.

The maximization of (6) under the budget constraint, $p_t x_{tk} + p_s x_{sk} + v_k = y_k$, where y_k

[17] One extension could also consider the value of information at stages *ii*, *iii* or *iv*.

denotes the income of person *k*, leads to the following inverse demand function for tuna and sardines

$$\begin{cases} p_t = \alpha_t - \beta_t x_{tk} - \gamma x_{sk} - I_j . r_{tk} \\ p_s = \alpha_s - \beta_s x_{sk} - \gamma x_{tk} + I_j . h_{sk} \end{cases} . \tag{7}$$

Note that a higher risk reduces the demand for tuna while a higher health benefit leads to a demand increase for sardines. Graphically speaking, the demand curve for tuna shifts downwards, whereas the demand curve for sardines shifts upwards. We consider both these shifts in the estimation of welfare change. By inverting (7), we obtain consumer *k*'s demand for tuna and sardines:

$$\begin{cases} x_{tk} = \dfrac{\alpha_t \beta_s - \alpha_s \gamma - \beta_s p_t + \gamma p_s - I_j(\beta_s r_{tk} + \gamma h_{sk})}{\beta_s \beta_t - \gamma^2} \\ x_{sk} = \dfrac{\alpha_s \beta_t - \alpha_t \gamma - \beta_t p_s + \gamma p_t + I_j(\gamma r_{tk} + \beta_t h_{sk})}{\beta_s \beta_t - \gamma^2} \end{cases} . \tag{8}$$

Aggregated market demand for tuna and sardines are given by $X_t = \sum_{k=1}^{K} x_{tk}$ and $X_s = \sum_{k=1}^{K} x_{sk}$.

Inverting these aggregated demands leads to the inverse demand functions

$$\begin{cases} p_t^{\,j} = \alpha_t - \dfrac{\beta_t}{K} X_t - \dfrac{\gamma}{K} X_s - I_j . \dfrac{\sum_{k=1}^{K} r_{tk}}{K} \\ p_s^{\,j} = \alpha_s - \dfrac{\beta_s}{K} X_s - \dfrac{\gamma}{K} X_t + I_j . \dfrac{\sum_{k=1}^{K} h_{sk}}{K} \end{cases} . \tag{9}$$

Using (9), the difference between aggregate inverse demands at period (*v*) and (*i*) is given by $p_t^{\,v} - p_t^{\,i} = -\sum_{k=1}^{K} r_{tk} / K$ for tuna and to $p_s^{\,v} - p_s^{\,i} = \sum_{k=1}^{K} h_{sk} / K$ for sardines.

For any subgroup *z* linked to the experiment, we will calibrate demands (without

[18] In particular, this specification omits the revenue effect.

information revelation) in correspondence to the proportion that the subgroup represents in the French population. Then, for a subgroup *z* and by using (5), it is possible to use the average change in willingness to pay for sardines, $\overline{\delta}_S^z$, over subjects in group A and B, and the average change in willingness to pay for tuna, $\overline{\delta}_T^z$, over subject in group C and D. By using the previous definition of $p_t^{\,v} - p_t^{\,i}$ and $p_s^{\,v} - p_s^{\,i}$, the average value of per-unit risks and per-unit benefits for the subgroup *z* are

$$\begin{cases} \overline{r}_t^{\,z} = \sum_{k=1}^{K_Z} r_{tk} / K_Z = -p_t^{\,i}\,\overline{\delta}_T^z \\ \overline{h}_s^{\,z} = \sum_{k=1}^{K_Z} h_{sk} / K_Z = p_s^{\,i}\,\overline{\delta}_S^z \end{cases}, \qquad (10)$$

where K_z is the number of people in a subgroup. Demand shifts are determined by taking into account values given in (10) where $p_t^{\,i}$ and p_s^i are given by the average market prices $\widehat{p}_t$ and $\widehat{p}_s$ in France in 2002 (see table 5). Using both endowments (tuna and sardines) in the experiment (leading to $\overline{\delta}_S^z$ and $\overline{\delta}_T^z$) is hence essential for solving equation (10). In the calibrated model, the aggregate responses coming from the experiment are integrated by taking into account the average values defined by (10).

We now turn to the description of the calibration of a partial equilibrium model of the French markets for canned tuna and canned sardines.

5.2 Calibration

Parameters of the model are calibrated such as to predict prices and quantities in France (under the absence of information) for the year 2002 (see table 5), the most recent complete year when the analysis was undertaken (OFIMER, 2003). The supply and demand equations are represented by linear approximations with the corresponding elasticity at the point of approximation. For the supply side, we assigned values to supply function such as $X_f = d_f + e_f p_f$ with f=t or s for tuna or sardines, with elasticities found in the literature. For the calibration of demands described in equation (8), we assigned values to the parameters based on elaticities that we estimated (see table 5).[19]

The aggregation of demands of different subgroups leads to the overall demand. We distinguish households consuming both types of fish from those only consuming tuna (e.g.,$\alpha_s = \beta_s = \gamma = 0$) or only consuming sardines (e.g.,$\alpha_t = \beta_t = \gamma = 0$). For calibrating the effect of information, we also distinguish consumers "at risk" for whom $\overline{r}_t^z$>0 and $\overline{h}_s^z$>0 from those "not at risk" for whom $\overline{r}_t^z$=0 and $\overline{h}_s^z$=0 (not concerned by the health message of this experiment).

For consumers "at risk", namely households with women of childbearing age and/or with young kids under age 14, we take the average values of equation (5) over all subjects of the experiment (namely the one switching and the one not switching) for determining $\overline{r}_t^z$ and $\overline{h}_s^z$ defined by (10). In this case, the average values (including also consumers who do not switch) are $\overline{\delta}_S = 1.28$ for groups A and B and $\overline{\delta}_T = -0.21$ for groups C and D. We also assumed that only demands of consumers consuming both types of goods (demand by consumers Ω_1 in table

[19] For subgroup z and by using (8) consider the overall demand for tuna without health information (at stage j=i) as given by $X_{tz}^i(p_t, p_s) = \sum_{k=1}^{K_z} x_{tk} = a_{tz} - b_{tz} p_t + g_{sz} p_s$. Denote observed average market prices $\widehat{p}_t$ and $\widehat{p}_s$ in France in 2002, annually purchased quantity of tuna by group z as $\widehat{X}_{tz}$, the own price elasticity $\widehat{\varepsilon}_{tt}$ and the cross-price elasticity $\widehat{\varepsilon}_{ts}$ (see table 5). The calibrated parameters are $b_{tz} = -\widehat{\varepsilon}_{tt} \widehat{X}_{tz} / \widehat{p}_t$, $g_{sz} = \widehat{\varepsilon}_{ts} \widehat{X}_{tz} / \widehat{p}_s$ and $a_{tz} = \widehat{X}_{tz} + b_{tz} \widehat{p}_t - g_{sz} \widehat{p}_s$.

5) were modified.[20]

The data used for estimating elasticities are drawn from the 2002 issues of a French household panel conducted by SECODIP (Société d'Etude de la Consommation, Distribution et Publicité) on household purchases.[21] 90% of households consume canned tuna and 57% consume canned sardines. We only focused on households that are consumers of caned tuna and/or canned sardines. We aggregated to quarterly expenditures in order to avoid the problem of purchase infrequency, assuming that households having no expenditures on tuna or sardines are a non-purchaser of that good. We eliminated the non-purchasers that buy neither tuna nor sardines. Observations were classified according to whether or not consumers purchase tuna and sardines (Ω_1), only tuna (Ω_2), or only sardines (Ω_3). The econometric model consisted in regressing log-quantities and log-prices and tuna (see table 5).

The equalization of aggregate demand and supply will lead to equilibrium prices that clear the market. We will directly use the prices adjustments for measuring producers' profits, surpluses of different consumer groups (including the cost/benefit of ignorance) and total welfare (see appendix C).

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[20] Alternatively, we distinguished subjects initially not interested in sardines (with $\widetilde{q_{Sard}}^{i} = 13$ for groups A and B and $\widetilde{q_{tuna}}^{i} = 1$ for groups C and D) from those initially accepting sardines, leading to results close to the ones given in table 6. For the subjects initially not interested by sardines, the average value (including also consumers who do not switch) is $\tilde{\delta}_S = 2.06$ and $\tilde{\delta}_T = -0.29$. These values would modify the demand that integrates the possibility to consume sardines after the revelation of information (demand by consumers Ω_2 in table 5). For subjects initially accepting sardines, the average value (including also consumers who do not switch) is $\hat{\delta}_S = 0.74$ and $\hat{\delta}_T = -0.19$. These values would modify the demands of consumers consuming both types of goods (demand by consumers Ω_1 in table 5). Effects are similar to the ones that will be presented in table 6, even if monetary values are different since the price increase for sardines is larger than in table 6.

[21] For 2002, the initial samples contain 5362 households. This survey contains detailed information on the attributes of households living in France and on their purchase behaviour regarding various consumption goods, including numerous food products. Each issue provides, over the whole year, a description of the main characteristics of the

To estimate the impact of information, we divided the populations (and the overall demands) according to their risk status and their consumption habits. The subgroup of households concerned by the information includes all households with women of childbearing age and/or with young kids under age 14.[22] From INSEE (1999), these households represent 50.5% of French consumers. For measuring different contexts of diffusion, we will distinguish the *case* 1, where all the 50.5% of concerned households receive health information and the *case* 2, where only half of these concerned consumers are reached by this information.[23] We now turn to the results.

5.3. Results

The table 6 provides the economic impact of information on prices and surpluses of agents over the year 2002 (see appendix C for details about the following expressions). The first lines present the respective variations in the price of tuna Δp_T and sardine Δp_S coming from the information revelation. The following lines denote the variation of surpluses coming from the information revelation and the resulting price variation. Recall that the variations of surplus are equal to the surplus with information less the surplus without information. For each line, a positive value means a benefit coming from the information, while a negative value means a loss coming from the information.

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goods, the purchased quantities and the corresponding expenditures.

[22] For simplicity, we considered that households without women of childbearing age or without young kids are not concerned by the revealed information, even if omegas 3 concern all the population for its impact on cardiovascular risk.

[23] An alternative assumption would consist in defining an optimal level of "advertising/promotion" with a function cost $C(\beta)$ with $C'(\beta), C''(\beta) > 0$ where β is the proportion of women receiving the information. It would be possible to use the table 1 p. 427 in Kinnucan and Myrland (2001) for values of promotion elasticity for France.

In table 6, $\Delta\Pi_T$ and $\Delta\Pi_S$ respectively denote the profits variations for the tuna producers and the sardines producers (without any change in their capital structure). ΔCS_1 denotes the surplus variation for the consumers not concerned by the information, namely "not at risk" for whom $\overline{r}_t^1$=0 and $\overline{h}_t^1$=0. ΔCS_2 denotes the surplus variation for the consumers "at risk" with $\overline{r}_t^2$>0 and $\overline{h}_t^2$>0 (see equation (C7) for details about case 1 and case 2). ΔW denotes the overall welfare variation. Eventually, we provide the surplus variation $\Delta\widetilde{CS}_2$ for consumers that are concerned by the revealed information under the simplifying assumption that initial prices were fixed (the other agents' surplus remains unchanged so that $\Delta\widetilde{W} = \Delta\widetilde{CS}_2$).

The demand shifts imply a fall in the equilibrium price for tuna ($\Delta p_T < 0$) and an increase in the equilibrium price for sardine ($\Delta p_S > 0$). Note that the price variation for sardines is larger than the absolute value of the price variation for tuna, since the average values of $\overline{\delta}_S$ for sardines are larger than the average values of $\overline{\delta}_T$ for tuna in our experiment. As consequences, gross profits for tuna producers fall, while gross profits for sardine producers surge.

Despite the subsequent price changes, concerned consumers/households benefit from the information since ΔCS_2 is positive. Consumers not concerned by the revealed information suffer from the subsequent change in market prices with a negative ΔCS_1. This loss comes from the large price increase for sardines that outweighs the positive impact of the small price decrease for tuna.

Table 6 shows a positive welfare gain to inform households or women despite some losses for tuna producers and for consumers not concerned by the revealed information. The net welfare gain ΔW is positive for all configurations presented in table 6. In other words, the benefits of information for concerned consumers and the better profits for sardines producers outweigh the losses for both tuna producers and consumers not concerned by the information.

The possibility to consider stable prices after the revelation of information with a consumer's surplus $\Delta\widetilde{CS}_2$ would lead to an overestimation of both consumers' surplus and welfare (measuring the value of information), since the ratios $\Delta CS_2 / \Delta\widetilde{CS}_2$ and $\Delta W / \Delta\widetilde{CS}_2$ given in the last rows of table 6 are relatively low. The relatively large price increase for sardines is costly for consumers that adjust their behavior in response to information, so that the benefit of the information on their surplus is partially thwarted by a negative effect coming from this price increase for sardines. This welfare overestimation with $\Delta CS_2 / \Delta\widetilde{CS}_2 < 1$ and $\Delta W / \Delta\widetilde{CS}_2 < 1$ was overlooked in the previous estimation of the value of information coming from experimental economics.

The sensitivity of the results was also studied. In particular, the effects presented in table 6 are relatively similar under alternative scenarios, even if monetary values are different. As table 6 shows, there is a social gain to inform women at childbearing age. However, table 6 only considers the efficacy of informing consumers, abstracting from the cost of information. It may though be reinterpreted for taking into account the overall monetary cost of information. As soon as the cost of information is lower than the net welfare gain (ΔW), a diffusion of information is socially desirable.

6. Conclusion

Public health communication about fish consumption is a difficult task because of the complexity of health risks and benefits that pose themselves in different weights for different parts of the population. In order to test the ability of benefit and risk advisories to change consumer behavior, we present results of an economic, non-hypothetical choice experiment involving the evaluation of substitution rates.

It turns out that the experimental procedures have important implications for the evaluation of product substitution. We show that the order of information and consumption recommendations matters. Efficiency of information can be improved by first talking about benefits before talking about risks, as then the information about benefits is still absorbed. It seems useful to begin an advisory to women at childbearing age by first insisting on the benefits coming from omega-3 polyunsaturated fatty acids, followed by a clear consumption recommendation.

Another important finding is the value of information mixing experimental results and a quantitative estimate applied to the French market for forecasting prices reactions and welfare variations. This new methodology could be used by policy bodies for *ex ante* estimation of labeling/recommendation policies for predicting market reactions through the introductions of experimental results into a partial market equilibrium model.

Of course, our results are limited to the substitution between two fish species. One extension should consider the introduction of more species, fully representing French consumption. Another extension should introduce the possibility for consumers to change their total fish consumption, since we voluntarily constrained their choices to a value equivalent to six cans. One way to relax the separability assumption of the two goods would consist in offering at the end of the experiment the possibility to exchange the six cans they received versus the numeraire, which would be consistent with Spence's quasi-linear utility model used in equation (6) or to measure WTP for each fish using, e.g., the Becker, Marshak and DeGroot (1964) mechanism. Another extension could give subjects the choice to obtain or refuse additional information during the experiment.

By correcting idiosyncratic characteristics, the experiment could also be replicated in other countries for better understanding consumers' reactions. It could complete studies focusing on women's observed reactions to fish consumption advisories. For instance, the methodology of this paper could be useful for directly tackling some points of the research agenda recently raised by the US *National Academies* (National Academies, 2006).

The experimental work on health information emphasizes that when an advisory is issued, it is imperative that the regulatory agency takes into account several important factors, such as consumers' reaction and preferences for some fish species, before deciding the type of information and/or the media to use. The results of this paper point to the importance of developing economic analyses prior to the diffusion of an advisory regarding methylmercury.

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Table 1. Description of fish cans

Connétable cans	Grams	Price per can in supermarket in 2005(€)	Price per kilogram (€)	Average price in France in 2002 (€)
Tuna (Albacore)	80	1.65	20.62	6.1
Sardine	87	1.69	19.42	8.2

Source: authors and Ofimer (2003) for the last column.

Table 2. Average content in omega-3s and in methylmercury for canned tuna and canned sardines in Europe

	Omega-3s (n-3 PUFA) in g/100g raw fish	Methylmercury in mg/kg fresh matter
Canned tuna	0.25 * 0.5 **	0.210***
Canned sardines	3.3 * and **	0.052

Sources: * EFSA (2005, table 23 p.63) and ** Sidhu (2003, table 5 p. 341) for omega-3s and Crépet et al. (2005, table 1, pp. 181-182) for methylmercury. ***The methylmercury level for canned tuna is a lower bound given by scenario 3 in table 1, p. 182 in Crépet et al. (2005).

Table 3. Experimental design

Initial Endowment (Fish I)	Information about Omega-3 fatty acids ((1a) and (1b)) Methylmercury ((2a) and (2b))	Information about Methylmercury ((2a) and (2b)) Omega-3 fatty acids ((1a) and (1b))
Tuna	**Group A** 27 women	**Group B** 31 women
Sardines	**Group C** 28 women	**Group D** 29 women

Table 4. Description of experimental groups

	Group A	**Group B**	**Group C**	**Group D**
Number of subjects	27	31	28	29
Number of subjects changing after omega-3 (1a)	8	9	11	7
Number of subjects changing after omega-3 recommendation (1b)	12	3	9	4
Number of subjects changing after mercury (2a)	8	11	9	8
Number of subjects changing after mercury recommendation (2b)	8	10	8	9
Number of subjects choosing 1 can of Fish II on any of the five sheets	13/135	12/155	21/140	19/145
Number of subjects choosing always Fish I on any of the five sheets	43/135	38/155	20/140	31/145
Number of subjects constantly choosing Fish I	5	5	2	3
Number of subjects constantly choosing Fish II	0	0	3	1

Table 5. Demand Specification for the households who purchase both canned Tuna and canned sardines in France in 2002

Variable	Description	Values	
Tuna	Overall consumption in France in 2002 (in tons)	63 845	
	Average price in 2002 (in euros)	6.1	
	Supply elasticity[1]	0.2	
Sardines	Overall consumption in France in 2002 (in tons)	11 484	
	Average price in 2002 (in euros)	8.2	
	Supply elasticity[1]	0.2	
Consumers	Ω_1 purchasing both sardines and tuna		
% of households consuming sardines and tuna[3]		65%	
	Demand elasticities[2]	Tuna	Sardines
	Own-price	–0.58*	–0.476*
	Cross-price	–0.059*	0.144*
Consumers	Ω_2 only purchasing tuna		
% of households consuming only tuna[3]		32.5%	
	Own-price elasticity of demand[2]	–0.534*	
Consumers	Ω_3 only purchasing sardines		
% of households consuming only sardines[3]		2.5%	
	Own-price elasticity of demand[2]	–0.451*	

Source: OFIMER 2003, Secodip 2002

[1] Supply ealsticities by Babula and Corey (2004) for tuna in the US where "fishery [are] exploited at or near its maximum yields" (see p.145). By lack of credible estimation for France, we assume that technologies between these two countries are similar. We also assume that sardines fisheries exhibit the same technology.

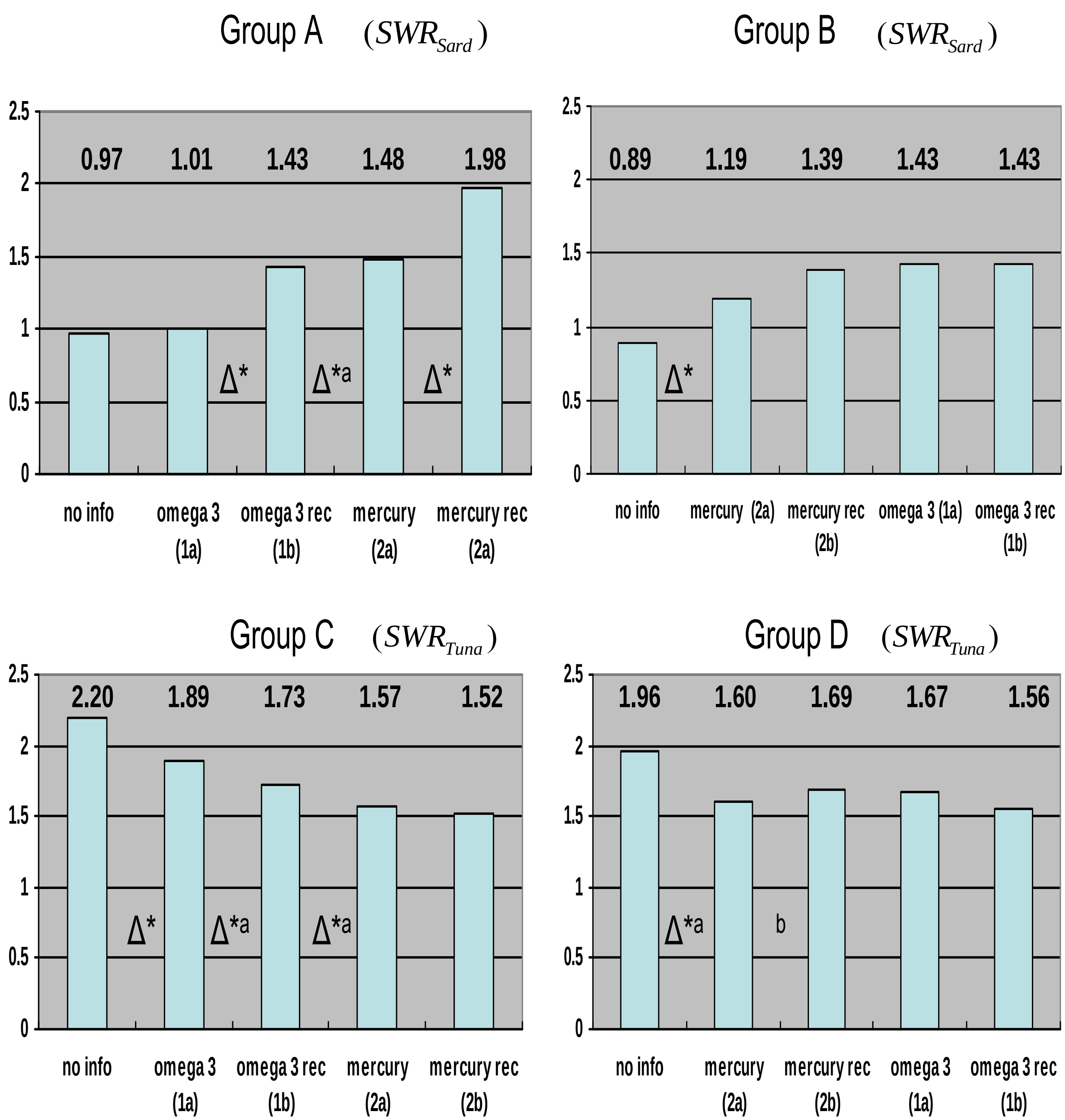
[2] Author Estimation for the elasticity with SECODIP 2002. * marks significance at the 5% level in the regression between the log of quantities and the log of prices.

[3] Percentage over the overall number of consumers only purchasing tuna or sardines.

Table 6. Economic effects of information to prices and different groups (in euros)

	Case 1	***Case 2***
Price variations		
Δp_T	–0.28	–0.14
$\Delta p_T / \widehat{p}_t$ (%)	–4.6%	–2.3%
Δp_S	3.70	1.85
$\Delta p_S / \widehat{p}_t$ (%)	45.2%	22.6%
Surplus variation when prices vary		
$\Delta\Pi_T$	–21 579 855	–10 832 098
$\Delta\Pi_S$	54 931 214	26 503 449
ΔCS_1	–13 830 515	–12 576 828
ΔCS_2	7 609 339	8 403 685
ΔW	27 130 183	11 498 207
$\Delta W / W$ (%)	2.8%	1.2%
Surplus variation with constant initial prices		
$\Delta\widetilde{CS}_2 (= \Delta\widetilde{W})$	40 196 836	20 098 418
$\Delta CS_2 / \Delta\widetilde{CS}_2$ (%)	18.9%	41.8%
$\Delta W / \Delta\widetilde{CS}_2$ (%)	67.4%	57.2%

Figure 1. Mean Switching-Point Quantities ($SWR_{II} = 6/\widetilde{q_{II}}$)



Note of figure 1: Δ* denotes significant difference at 5% as tested by the Wilcoxon test for comparing paired sample choices $SWR_{II}{}^{j}$ and $SWR_{II}{}^{j+1}$ with $j \in \{i,v\}$ for the different stages of information revelation. [a] denotes differences are no longer significant when testing after deleting extreme observations of $q_{II}=1$ or $q_{II}=13$. [b] denotes differences that become significant when testing after deleting observations of $q_{II}=1$ or $q_{II}=13$. On the X axis, "Omega3 rec" and "mercury rec" means that a recommendation were revealed to subjects (see section 3.4).

APPENDIX A

The precise messages are translated from the original French.

Messages linked to the omega-3 fatty acids

Message (1a) for groups A and B (with the endowment of 6 cans of tuna)
Fish is important for the diet equilibrium. Fish is a good source of proteins, vitamins, and minerals. Fish content is high in omega-3 fatty acids and low in saturated fat.
Tuna contains six-fold less omega-3 fatty acids than sardines.

Message (1a) for groups C and D (with the endowment of 6 cans of sardines)
Fish is important for the diet equilibrium. Fish is a good source of proteins, vitamins, and minerals. Fish content is high in omega-3 fatty acids and low in saturated fat.
Sardines contain six-fold more omega-3 fatty acids than tuna.

Message (1b) for all groups
The regular consumption of omega-3 fatty acids helps to reduce the risks of cardiovascular diseases and it contributes to brain development and growth of children. Public health authorities advise eating fish at least twice a week.

Messages linked to the methylmercury

Message (2a) for groups A and B (with the endowment of 6 cans of tuna)
Fish contains methylmercury (organic form of mercury) naturally present in water and coming from industrial pollution. All fish contain traces of methylmercury. By accumulation, larger fish that have lived longer have the highest level of methylmercury. Tuna contains four-fold more methylmercury than sardines.

Message (2a) for groups C and D (with the endowment of 6 cans of sardines)
Fish contains methylmercury (organic form of mercury) naturally present in water and coming from industrial pollution. All fish contain traces of methylmercury. By accumulation, larger fish that have lived longer have the highest level of methylmercury. Sardines contain four-fold less methylmercury than tuna.

Message (2b) for all groups
The mercury effects on health have been shown by several medical studies. The results of these studies show a lack of brain development in the fetus and in children exposed to mercury. Public health authorities advise pregnant women, childbearing women and young children to avoid the consumption of predatory fish such as tuna.

APPENDIX B

The 12 situations to select for groups A and B.

Situation 1	O 6 tuna cans	**or**	O 1 sardine can
Situation 2	O 6 tuna cans	**or**	O 2 sardine cans
Situation 3	O 6 tuna cans	**or**	O 3 sardine cans
Situation 4	O 6 tuna cans	**or**	O 4 sardine cans
Situation 5	O 6 tuna cans	**or**	O 5 sardine cans
Situation 6	O 6 tuna cans	**or**	O 6 sardine cans
Situation 7	O 6 tuna cans	**or**	O 7 sardine cans
Situation 8	O 6 tuna cans	**or**	O 8 sardine cans
Situation 9	O 6 tuna cans	**or**	O 9 sardine cans
Situation 10	O 6 tuna cans	**or**	O 10 sardine cans
Situation 11	O 6 tuna cans	**or**	O 11 sardine cans
Situation 12	O 6 tuna cans	**or**	O 12 sardine cans

The 12 situations to select for groups C and D.

Situation 1	O 6 sardine cans	**or**	O 1 tuna cans
Situation 2	O 6 sardine cans	**or**	O 2 tuna cans
Situation 3	O 6 sardine cans	**or**	O 3 tuna cans
Situation 4	O 6 sardine cans	**or**	O 4 tuna cans
Situation 5	O 6 sardine cans	**or**	O 5 tuna cans
Situation 6	O 6 sardine cans	**or**	O 6 tuna cans
Situation 7	O 6 sardine cans	**or**	O 7 tuna cans
Situation 8	O 6 sardine cans	**or**	O 8 tuna cans
Situation 9	O 6 sardine cans	**or**	O 9 tuna cans
Situation 10	O 6 sardine cans	**or**	O 10 tuna cans
Situation 11	O 6 sardine cans	**or**	O 11 tuna cans
Situation 12	O 6 sardine cans	**or**	O 12 tuna cans

APPENDIX C: Definition of producers' and consumers' surplus

With an overall supply $X_f = d_f + e_f p_f$ with f=t or s for tuna or sardines, the overall gross profit for an equilibrium price p is $\Pi_f(p) = \int_0^p (d_f + ep_f)dp_t$.

For a subgroup z with a demand without information (at stage j=i) given by $X^i_{tz}(p_t, p_s) = a_{tz} - b_{tz}p_t + g_{sz}p_s$ for tuna (see footnote 19) and $X^i_{sz}(p_t, p_s) = a_{sz} - b_{sz}p_s + g_{tz}p_t$ for sardines, and observed average prices $\hat{p}_t$ and $\hat{p}_s$ in France in 2002 (see table 5), the consumer surplus (at stage j=i) is

$$CS^i_z = \int_{\hat{p}_t}^{p^0{}_{ti}} X^i_{tz}(p_t, \hat{p}_s)dp_t + \int_{\hat{p}_s}^{p^0{}_{si}} X^i_{sz}(\hat{p}_t, p_s)dp_s\,, \tag{C1}$$

where p^0_{ti} is such that $X^i_{tz}(p^0_{ti}, \hat{p}_s) = 0$ and p^0_{si} is such that $X^i_{sz}\left(\hat{p}_{t,} p^0_{si}\right) = 0$. Following Polinsky and Rogerson (1983) and Teisl et al. (2001), the cost/benefit of ignorance linked to the lack of information and internalization is also considered in the surplus/welfare. By using (10), the cost/benefit of ignorance to consider is given by

$$IG^i_z = -\bar{r}^z_t X^i_{tz}(p_t, p_s) + \bar{h}^z_s X^i_{sz}(p_t, p_s)\,. \tag{C2}$$

The overall consumer surplus integrating the cost/benefit of ignorance is $CS^i_z + IG^i_z$.

After the complete revelation of information at stage v, the new demands are $X^v_{tz}(p_t, p_s) = a_{tz} - b_{tz}p_t + g_{sz}p_s - b_{tz}\bar{r}^z_t - g_{sz}\bar{h}^z_t$ for tuna (see equation (8) and footnote 19 for details) and $X^v_{sz}(p_t, p_s) = a_{sz} - b_{sz}p_s + g_{tz}p_t + g_{tz}\bar{r}^z_t + b_{sz}\bar{h}^z_t$. The new equilibrium prices $\tilde{p}^v_t$ and $\tilde{p}^v_s$ are computed via the calibrate model. The consumer surplus (at stage j=v) is

$$CS_z^v(\bar{r}_t^z, \bar{h}_s^z) = \int_{\tilde{p}_t^v}^{p^0_{tv}} X_{tz}^v(p_t, \tilde{p}_s^v)dp_t + \int_{\tilde{p}_s^v}^{p^0_{sv}} X_{sz}^v(\tilde{p}_t^v, p_s)dp_s\,. \qquad \text{(C3)}$$

We are now able to detail the expressions given in table 6. Using previous notations the price variations for tuna and sardines are respectively

$$\begin{cases} \Delta p_T = \tilde{p}_t^v - \hat{p}_t \\ \Delta p_S = \tilde{p}_s^v - \hat{p}_s \end{cases} \qquad \text{(C4)}$$

The profit variations for tuna producers and sardine producers are

$$\begin{cases} \Delta \Pi_T = \Pi_t(\tilde{p}_t^v) - \Pi_t(\hat{p}_t) \\ \Delta \Pi_S = \Pi_s(\tilde{p}_s^v) - \Pi_s(\hat{p}_s) \end{cases} \qquad \text{(C5)}$$

By using (C1), (C2) and (C3), the surplus variation for the consumers not concerned by the information, namely "not at risk" for whom $\bar{r}_t^1$=0 and $\bar{h}_s^1$=0 (leading to $IG_1^i = 0$, $X_{t1}^i(p_t, p_s) = X_{t1}^v(p_t, p_s)$ and $X_{s1}^i(p_t, p_s) = X_{s1}^v(p_t, p_s)$) is

$$\Delta CS_1 = CS_1^v(0,0) - CS_1^i \qquad \text{(C6)}$$

The surplus variation for the consumers "at risk" is the following. For a proportion β of consumers "at risk" receiving the information, the parameters $\bar{r}_t^2$>0 and $\bar{h}_s^2$>0 (with $IG_2^i \neq 0$) leads to overall surplus $CS_2^i + IG_2^i$ and $CS_2^v(\bar{r}_t^2, \bar{h}_s^2)$. For a proportion (1-$\beta$) of consumers "at risk" receiving no information, the parameters $\bar{r}_t^2$>0 and $\bar{h}_s^2$>0 (with $IG_2^i \neq 0$) are not internalized in the demand in period *v* which leads to overall surplus $CS_2^i + IG_2^i$ at period *i* and $CS_2^v(0,0) + IG_2^i$ at period *v*. For this group the surplus difference between both periods is $CS_2^v(0,0) - CS_2^i$ because of prices changes. The overall surplus variation is then

$$\Delta CS_2 = \beta[CS_2^v(\overline{r}_t^2, \overline{h}_s^2) - (CS_2^i + IG_2^i)] + (1-\beta)[CS_2^v(0,0) - CS_2^i]. \tag{C7}$$

Under case 1, the proportion β is equal to 1 while, under case 2, the proportion β is equal to 1/2.

The overall welfare variation ΔW is equal to the sum of surplus variations defined by (C5), (C6) and (C7).

Eventually, for a scenario with constant prices in table 6, namely for $\tilde{p}_t^v = \hat{p}_t$ and $\tilde{p}_s^v = \hat{p}_s$, the variation are $\Delta\Pi_T = \Delta\Pi_S = \Delta CS_1 = 0$, the surplus variation given by (C7) leads to $\Delta\widetilde{CS}_2 = \beta[CS_2^v(\overline{r}_t^2, \overline{h}_s^2) - (CS_2^i + IG_2^i)]$ for consumers that are concerned by the revealed information, since $CS_2^v(0,0) = CS_2^i$ with constant prices.