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The Combination of Lab and Field Experiments for Benefit-Cost Analysis

Stéphan Marette, Jutta Roosen, and Sandrine Blanchemanche

Abstract

This article explores the combination of laboratory and field experiments in defining a welfare framework and the impact of different regulatory tools on consumer behaviors. First, an overview of strengths and weaknesses raised by the experimental literature show that, for food consumption, lab and field experiments may be complementary to each other. The lab experiment elicits willingness to pay useful for determining per-unit damages based on well-informed, thoughtful preferences, while the field experiment determines purchase/consumption reactions in real contexts. Second, the analytical approach suggests how to combine the results of both lab and field experiments to determine the welfare impact of different regulatory tools such as labels and/ or taxes. Third, an empirical application focuses on a lab and a field experiment conducted in France to evaluate the impact of regulation on fish consumption. Estimations for the French tuna market show that a per-unit tax on tuna and/or an advisory policy lead to welfare improvements.

KEYWORDS: regulation, instruments, lab and field experiments, food consumption, France

1. Introduction

Reliable information about markets and credible consumer valuations regarding safety and/or public goods are the Achilles' heel of benefit-cost analysis (BCA) (Robinson and Hammitt, 2011). Laboratory and field experiments, in a complementary way, provide precious information about consumers' valuation for improving BCA.

Many studies elicit consumers or citizens' willingness-to-pay (WTP) via lab experiments and numerous field experiments study consumer behavior in real contexts (Lusk and Shogren, 2007). Many papers, however, stop at measuring WTP and do not actually derive welfare measures associated with regulatory instruments such as Pigouvian taxes, product minimum-quality standards, labels and/or tax credits. We state that more applied welfare studies on regulatory instruments would help public debates and complete the theoretical literature.

This paper focuses on the integration of WTP elicited in a lab and consumption reactions determined in the field in a partial equilibrium model for determining welfare impacts of different regulatory instruments. The experimental literature detailed in section 2 shows that, for food, lab and field experiments are generally complements. The lab experiment elicits WTP useful for determining per-unit damages based on well-informed, thoughtful preferences, and the field experiment determines purchase and consumption reactions in real contexts where consumers lack attention and/or recall.

With a partial equilibrium model used for welfare analysis, we show how to take into account the consumption variations determined in the field with the integration of lab results to evaluate the damage for consumers. Our purpose is to show that the combination of consumer reaction coming from the field and WTP estimates derived from the lab may lead to a regulatory analysis detailing the impact of instruments as a per-unit tax, a minimum-quality standard or a label. We investigate the welfare impact of these instruments.

We illustrate the proposed procedure in the context of risks associated with dietary exposure to methyl-mercury. Excessive consumption of certain fish such as tuna can increase health risks of children, infants and fetuses because of methyl-mercury contamination. Risk-benefit analyses based on toxicological exposure assessment show that children and fetus of women who consume large amounts of fish during pregnancy are particularly vulnerable to the adverse neurological effects of methyl-mercury (Verger et al., 2007). Tuna is an important contributor to the methyl-mercury exposure since its concentration in mercury is high and it is the first fish consumed in France. The regulatory choices to curb this risk are complex since some nutrients in fish like omega-3 are also essential to the health of a developing fetus. Regular consumption of omega-3 rich fish is crucial for fetus and women. Per-unit tax, safety standard or recommendation/label could

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be implemented for capping methyl-mercury exposure. Some countries issued recommendations to vulnerable groups (see section 4). Defining a policy *ex ante* with only a toxicological exposure assessment is hard and incomplete since it gives no information about market mechanisms and consumers' risk perceptions and behaviors.

In order to investigate the regulatory problem linked to methyl-mercury in fish, two experiments were used. At the time, conducting two experiments in France was interesting because of the absence of major campaign of information about methyl-mercury.[1] On the one hand, we conducted a lab experiment in Dijon (France) for focusing on choices by women defined at risk (i.e. childbearing age) between two types of canned fish, sardines and canned tuna, since these fish have the opposite position regarding their concentration in omega-3 and methyl-mercury. Choice sessions were conducted before and after the revelation of health information with performance-based financial incentives, since participants were committed by one of their choices selected at the end of the experiment. The lab provides an environment that enhances consumers' ability to focus and thus elicit well-informed and thoughtful preferences. On the other hand, a field experiment was conducted in Nantes (France). Over five months, we followed the fish consumption of households defined as "at risk" (with women of childbearing age and children under 15), who were randomized into treatment and control groups. Only the treatment group received a message revealing health information about risks and benefits of fish consumption at the beginning of the second month. The message used was based on the consumer advisory disseminated in several OECD countries (see section 4).

Results show that information matters in both experiments, but does so in different ways. In the lab, the decrease in the WTP for canned tuna after the revelation of health information is statistically significant. In the field experiment, a difference-in-difference model shows that the decrease in consumption of canned tuna following the information revelation is relatively small but statistically significant. Through the calibrated model integrating experimental results in a partial-equilibrium model representing the tuna market in France, a welfare analysis shows that a per-unit tax on tuna internalizing the damage and/or an advisory policy lead to welfare improvements.

Despite the limitations in both experiments and welfare estimations, the effects of instruments computed in this study are informative simulations that provide credible suggestions for policy. The chosen instruments are driven by consumers/citizens preferences and welfare maximization.

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[1] This statement is still valid at the time of the writing of this paper.

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Our paper contributes to the literature on BCA and behavioral economics. Preference and choice inconsistencies discovered in behavioural economics question the evaluation of regulatory options based on these inconsistent preferences (see Sudgen, 2009, Robinson and Hammitt, 2011). In order to reduce the weight of potentially incoherent preferences, Smith and Moore (2010) suggest taking into account additional constraints explaining inconsistencies in the BCA. Our paper directly considers such a constraint linked to the imperfect recall by consumers after the revelation of an advisory in the field experiment. In our paper, both lab and field experiments allow the analysis to catch differences between a lab context where well-informed, thoughtful preferences are elicited and a field context where imperfect recall, lack of time before purchasing or/and confusion about complex information characterize many consumers in the supermarket purchasing environment.

This paper also contributes to the literature on BCA by focusing on the choice of regulatory instruments maximizing welfare. Both limits and distortions coming from instruments are directly taken into account in the welfare maximization. This differs from classical BCA where distortions linked to different regulatory instruments are not always precisely characterized (see Hahn and Tetlock (2008) and Hahn (2010) for new insights regarding the distortions that should be taken into account). This strengthens the role of BCA by focusing on the question “how to intervene?” rather than “when to intervene?”, which may improve regulatory decisions.

Moreover, we suggest that the role of information should be examined in relation with other regulatory instruments such as taxes or standards for questioning its efficiency. This differs from papers focusing only on labels impact (see for instance Bureau et al., 1998, Crespi and Marette, 2001, Marette and Crespi, 2003, Teisl et al., 2002, Verbeke, 2005 and Shimshack et al., 2007).

Eventually, this paper also adds to the experimental literature by providing what we believe to be the first welfare analysis of different regulatory options based on the combination of different types of experiments. Previous papers dealing with welfare/surplus mainly focused on the welfare impact of information revealed in a lab experiment and significantly impacting WTP. The welfare impact of information revealed in the lab was studied by Colson et al. (2008), Hu et al. (2005), Huffman et al. (2003 and 2007), Lusk et al. (2005), Lusk and Marette (2010), Marette et al. (2008a and 2008b), Masters and Sanogo (2002), Roosen and Marette (2011), Rousu et al. (2004 and 2007), Rousu and Shogren (2006), Rousu and Corrigan (2008) and Rousu and Lusk (2009). These previous studies are important for public debate, but extending the choice of regulatory instruments with measures coming from the field may strengthen the contribution of experimental data.

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The next section introduces important results coming from the literature on lab and field experiments and focuses on validity of experiments. We then present the theoretical framework used for estimating welfare changes with experimental data. Section 4 describes the experiments on fish consumption. Section 5 details the applied welfare estimation linked to different instruments. Section 6 presents some extensions, while the last section concludes.

2. Strengths and Weaknesses of Lab and Field Experiments

Important results of the behavioural/experimental economics challenge the ability to realize BCA. Sudgen (2009) underlines preference anomalies in environmental evaluation that may disqualify the validity of BCA. Basically preference inconsistencies discovered in behavioural economics (namely the impact of psychological attributes of the choice context, time preferences and differentiating between private and social preferences) question the evaluation of regulatory options based on these inconsistent preferences (see Robinson and Hammitt, 2011).

Smith and Moore (2010) suggest that one way to reduce the weight of certain incoherent preferences when conducting BCA is to take into account additional constraints explaining inconsistencies such as the framing of the decision context, the lack of time by consumers for thinking about consequences of decisions and/or the limited ability to collect, understand and recall information, etc. Experimental economics may shed light on some anomalies and may help considering some additional constraints in BCA as suggested by Smith and Moore (2010).

Experimental validity that is questioned by many papers is crucial for making credible BCA. Internal validity is the ability to demonstrate that observed correlations are causal and external validity is the ability to generalize the relationships found in a study to other contexts. The debate can be briefly summarized as following.

First, List and Levitt (2007) show that if individuals care about wealth and morality the importance given to morality in the lab depends, in part, on the extent to which one's actions are scrutinized. Because experimental subjects know they are being observed in experiments, results from the lab may fail to reflect the reality, which generates biases in welfare valuations. This effect is particularly salient for studies on charity or contributions to public goods that are not at stake in our experiments. List and Levitt (2007, p.170) argue that “lab experiments generally exhibit a special type of scrutiny, a context that places extreme emphasis on the process by which decisions and allocations are reached, and a particular selection mechanism for participants.”

Despite these criticisms, Falk and Heckman (2009) insist on the advantages of the lab allowing for tight control of both, environments and participants' actions. They mention that testing some theories such as the link between fair-wage and workers' effort with field data is notoriously difficult because too many different incentives may influence workers. Kagel and Roth (2000) show that simple experiments were crucial to show the stability of algorithms in matching markets, while field experiments were limited. Falk and Heckman (2009) underscore that lab and field experiments are complements. It is often the context and the type of questions that matters for judging the validity of lab and/or field experiments.

For food or other products sold in supermarkets like household cleaners or clothes, a significant number of papers support the external validity of lab experiments suggesting that lab results can be used for BCA. These papers directly compare the results of a laboratory experiment with those of market data or field experiments in stores.[2] Shogren et al. (1999) showed that lab evaluations and market shares coincide at high price valuations, supposedly selecting the truly interested consumers. Lusk and Fox (2003) have shown that field valuations were greater than laboratory valuations. Lusk et al. (2006) clearly show that the experimental results correspond well with actual retail sales. Chang et al. (2009) show a high level of external validity with non-hypothetical elicitation approaches able to predict retail sales. The relative proximity between lab and field experiments with food can be explained by (*i*) the similarity of stakes in both experiments (namely, similar products sold for decisions taken under both contexts), (ii) the absence of impact coming from differences between experienced and inexperienced participants.

Lusk et al. (2006) and Lusk and Norwood (2009) show that differences between behavior in the lab and the field are observed when there are social concerns, namely for food with normative or ethical attributes (as fair trade or animal welfare). As explained above, scrutiny by the lab organizer matters when the "morality" dimension cannot be ruled out.[3] Beyond this problem, Roe and Just (2009) argues that laboratory experiments tend to have more internal validity and field experiments more external validity. With food and under the absence of ethical attributes, measures coming from the lab seem reliable for BCA, even if no definitive conclusion can be taken. Based on the previous literature review, we

[2] Numerous studies exist that evaluate different choice mechanisms in lab experiments, as Lusk and Schroeder (2006) who compare auction mechanisms with results of non-hypothetical choice experiments.

[3] Note that with our lab experiment (as presented in section 4), 44% of participants did not change their valuations/preferences after the revelation of information. Such a figure suggests that the feeling of being scrutinized by organizers was not pervasive among participants.

consider our lab experiment on fish consumption as valid for determining thoughtful preferences regarding methyl-mercury risk.

With both experiments briefly presented in the introduction and detailed in section 4, many elements suggest that both experiments are complements because concerned products, recruitments and messages are very close, which allows their use for a welfare analysis. In the lab, participants give 'focal' attention on precise information (sensory and health risk/benefit) leading to well-informed, thoughtful preferences. Conversely, in the field, their attention can be diverted by many events in the supermarket like promotion, advertising or by the absence of recall when information is revealed a long time before the real purchase, as it is the case with the advisory used in the following field experiment (section 4). The absence of time, recall and attention by consumers when they purchase goods in supermarkets may explain their absence of reaction. Risks of consumers' confusion and difficulties to understand complex recommendations also diminish the information efficiency (see Blanchemanche et al., 2010, Marette, 2010 and Sasaki et al., 2011).

The following section shows how to integrate both WTP and consumption shifts coming from experiments in a calibrating model for making welfare analysis. As tuna is particularly important regarding the mercury risk, we consider a partial-equilibrium model for tuna only (extensions could easily consider other fish).

3. A Simple Model for Integrating Lab and Field Results

We now present a simple model that particularly matches issues linked to the lab/field experiments on food and more particularly for tuna.

On the demand side, we consider two types of consumers: the concerned consumers with a utility impacted by the risk linked to some specific fish (namely the methyl-mercury that is potentially harmful for pregnant women, kids and women of childbearing age) and the non-concerned consumers without any problem linked to the methyl-mercury (men and women over 45).[4] This division fits the experiment, where the concerned consumers are women and kids. More refined subdivisions of groups could be envisaged (see section 6).

In this simplified framework, we focus on one product, namely tuna. Demand of each consumer $i=\{1,\ldots,N\}$ is derived from a quasi-linear utility function that consists of the quadratic preference for the market good of interest and is additive in the numeraire:

$$U_i(q_i, w_i) = aq_i - \bar{b}q_i^2/2 - I_i r_i q_i + w_i, \tag{1}$$

[4] Including all women of childbearing age for being at risk is a simplification, as some women may have terminated their family planning beforehand.

where q_i is the consumption of the product. The parameters $a, b > 0$ allow to capture the immediate satisfaction from consuming products and w_i is the numeraire good.

The negative effect coming from fish is captured by the term $-I_i r_i\, q_i$ with the per-unit damage r_i (computed with the lab experiment as detailed below). The parameter I_i represents the consumer knowledge regarding the damage (linked to the information revealed in the field with the limited recall of fish species). If the consumer in the field is not aware of the characteristic at the time of the purchase, then I_i=0. However, the characteristic is accounted for in the welfare via the non-internalized damage, $r_i\, q_i$. Conversely, I_i=1 means that the consumer is aware of the characteristic r_i and internalize it in the consumption.

The maximization of utility defined by (1) with respect to q_i, subject to the budget constraint with a price p gives inverse demands $p = Max\left[0, a - I_i r_i - \bar{b} q_i\right]$ and the demand $q_i^D(p, I_i) = Max\left[0, (a - I_i r_i - p)/\bar{b}\right]$.

Individual demands are aggregated by subgroups making sense for the regulatory debate tackled by this paper. It is assumed that a proportion $\beta = N_1/N$ of consumers (women and kids) are concerned by the damage, with $r_i \geq 0$ for every i=1,…, N_1. Among them, a proportion γ internalized the advisory (I_i=1) with $\gamma\beta = \bar{N}_1 / N$ and $\bar{N}_1 \leq N_1$. Conversely a proportion $(1-\gamma)\beta = (N_1 - \bar{N}_1)/N$ does not internalize it (with I_i=0) because of a lack of recall or attention regarding the advisory given to all concerned consumers. The proportion $(1-\beta) = 1 - N_1/N$ is not concerned by this characteristic with $r_i = 0$ (namely, men and women over 45).

With $b = \bar{b}/N$ and $\gamma\beta = \bar{N}_1 / N$, the aggregate demands by concerned and informed consumers (I_i=1) is $Q_1^{1D}(p, \gamma) = \sum_{i=1}^{\bar{N}_1} q_i^D(p, 1)$ $= Max\left[0, \gamma\beta\left(a - p\right)/b - \sum_{i=1}^{\bar{N}_1} r_i \;/\bar{b}\right]$. It is assumed that r_i for every consumer i={1,…, $\bar{N}_1$} is given by the average value $E(r)$ based on the relative variation in WTP elicited in the lab if the variation is statistically significant (see below). $E(r)$ is an average measure of the well-informed, thoughtful preferences coming from the lab where participants were concerned women. The value $r_i = E(r)$ for every i={1,…, $\bar{N}_1$} leads to $\sum_{i=1}^{\bar{N}_1} r_i \;/\bar{b} = \gamma\beta E(r)/b$ and to an aggregated demand $Q_1^{1D}(p, \gamma) = Max\left[0, \gamma\beta\left(a - E(r) - p\right)/b\right]$.

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The aggregate demand for concerned and non-informed consumers is $Q_1^{0D}(p,1-\gamma)=\sum_{i=1}^{N_1-\bar{N}_1} q_i^D(p,0)=Max\left[0,(1-\gamma)\beta(a-p)/b\right]$ with a non-internalized damage given by $E(r)Q_1^{0D}(p,1-\gamma)$. For the non-concerned consumers, with $r_i=0$, the demand is $Q_2^D(p)=\sum_{i=1}^{N-N_1} q_i^D(p)=Max\left[0,(1-\beta)(a-p)/b\right]$.

For these three groups of consumers, the inverse demands are respectively

$$\begin{cases} p_1^{1D}(Q,\gamma)=Max\left[0,a-E(r)-\dfrac{bQ}{\gamma\beta}\right] \\ p_1^{0D}(Q,1-\gamma)=Max\left[0,a-\dfrac{bQ}{(1-\gamma)\beta}\right] \\ p_2^D(Q)=Max\left[0,a-\dfrac{bQ}{(1-\beta)}\right] \end{cases} \qquad (2)$$

The supply side with a perfectly competitive industry and price-taking firms is defined by P_R. We assume a perfectly elastic producer supply represented by constant returns to scale technology, implying zero producer profits (under the absence of sunk costs linked to the label, which is a simplifying assumption).

We now turn to the analysis of welfare effects of policy instruments. To further simplify, it is assumed that regulation is costless for firms and taxpayers. Administrative cost could be withdrawn from welfare variation for decided whether or not to implement a regulatory measure (see comments at the end of section 5).

Because of a lack of precise data, we also abstract from a minimum-quality standard limiting the concentration of mercury in fish, where highly contaminated fish would be banned from the market, which increases the fish price. The minimum-quality standard can be easily integrated in our model.

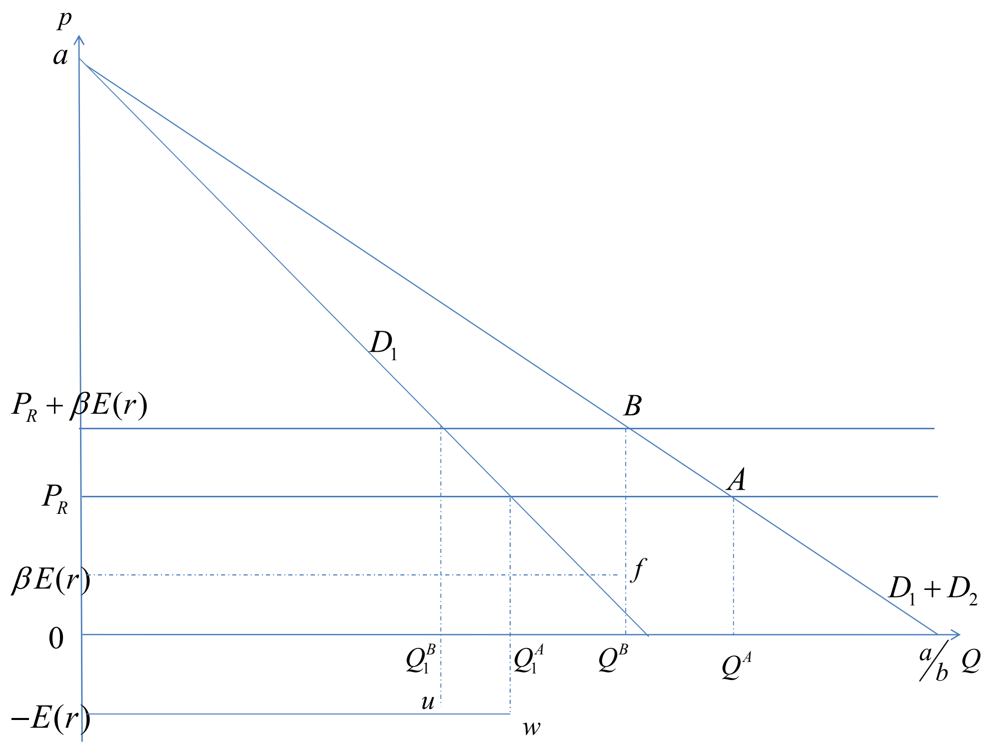
The previous assumption leads us to study 3 regulatory scenarios and to compare them to the absence of regulation, namely (*i*) a per-unit tax on the product, (*ii*) an advisory given to concerned population (via doctors, maternity and/or booklets), (*iii*) a per-unit tax combined with an advisory. The combination of instruments will be considered in the application but not detailed because of lack of space.[5]

Before detailing each scenario, we first present the market under the absence of regulation. Figure 1 shows demands and supplies. The price is located

[5] A label directly posted on products/packages or in restaurants is not considered since very few labels about mercury are posted in Western countries.

on the vertical axis and the quantity is shown along the horizontal axis. The supply is represented by P_R.

Figure 1. Market mechanisms: baseline (without regulation) and per-unit tax



Under the absence of intervention, the proportion β of concerned consumers is "interested" by the damage even if they do not internalize it in their consumption (*I*=0). Questionnaires of experiments showed that almost no French women were aware of mercury problems because of the absence of revealed information. This subgroup of concerned consumers has an overall demand D_1. The proportion $(1-\beta)$ of consumers is completely indifferent to the damage with a demand D_2 (not represented in figure 1). The overall demand is D_1+ D_2.

For this initial situation without policy intervention, there is a single equilibrium price P_R with a market clearing equilibrium quantity Q^A of the product (equilibrium *A*). The non-internalized damage incurred by concerned consumers in proportion β should be accounted for in the welfare calculation. This non-internalized damage is defined by $E(r)Q_1^A$ and represented by area $0(-E(r))wQ_1^A$, where Q_1^A is the consumption of the concerned consumers with a

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demand D_1 at price P_R. Consumers' surplus (area $P_R Aa$) minus the non-internalized damage yields an overall welfare represented by area $P_R Aa - 0(-E(r))wQ_1^A$.

Regulation is necessary for thwarting the absence of damage internalization by concerned consumers. We successively detail the impacts of regulatory scenarios.

Scenario #1: The per-unit tax on the product

A Pigouvian per-unit tax $P_R + t^*$ increases the price of this product without eliminating the damage. As we assume that no information is revealed with the tax, consumers are not informed (and the field experiment does not account). The tax t^* equal to $\beta E(r)$ maximizes the welfare defined by the sum of consumers' surplus, non-internalized damage and tax income.[6] The equilibrium price of the product is $P_R + \beta E(r)$ with a market clearing equilibrium quantity Q^B (equilibrium B in figure 1). The price increase hurts consumers and this related decrease in surplus is only outweighed by the damage decrease for concerned consumers. For the proportion β of concerned consumers, the non-internalized damage is defined by $E(r)Q_1^B$ and represented by area $0(-E(r))uQ_1^B$, where Q_1^B is the consumption of concerned consumers at price $P_R + \beta r$. The tax income for the regulator is $\beta E(r)Q^B$ represented by area $0(\beta E(r))fQ^B$. Adding the consumer surplus (area $(P_R + \beta E(r))Ba$) to the tax income and subtracting the non-internalized damage yields an overall welfare represented by area $(P_R + \beta E(r))Ba - 0(-E(r))uQ_1^B + 0(\beta E(r))fQ^B$.

Scenario #2: The Advisory

The effect of the advisory delivered to women is measured by the field experiment. The advisory delivered by internet or by booklets provided by gynecologists or before pregnancy has the advantage to only reach the concerned people. Non-concerned consumers are not uselessly informed and frightened. If the field experiment reveals significant consumption changes following the advisory, the consumption variation can be taken into account.

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[6] Analytical details can be provided upon request. We do not examine the use of the tax income by the regulator.

Figure 2. Market mechanisms: Advisory

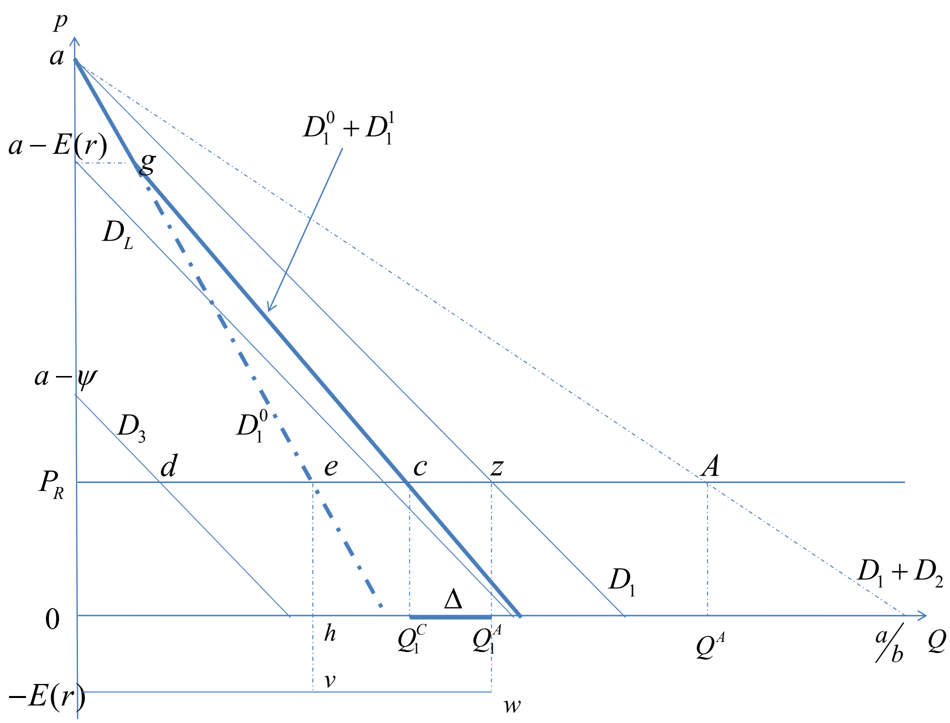

Figure 2 shows how concerned consumers can react when they receive the message in the field. Figure 2 starts from figure 1 by focusing on the proportion β of concerned consumers interested by the damage with a demand D_1 (the overall demand D_1+D_2 is represented by a dashed line in figure 2). Among these concerned consumers, a proportion γ internalized the advisory with a new demand D_1^1 that is not represented in figure 2 for simplicity and given by the first line of equation (2). The intercept of D_1^1 is $a-E(r)$ since the damage is internalized. Due to a lack of recall or attention, a proportion $(1-\gamma)$ of consumers with a demand D_1^0 does not internalize it even if the advisory reaches all the concerned people. The new demand $D_1^1+D_1^0$ following the advisory is represented by the bold curve in figure 2. The field experiment allows us to determine the average demand shift, $\Delta=Q_1^A-Q_1^C$. Based on the average value *E(r)* given by the lab and Δ given by the field, the proportion γ can be determined (as explained below in section 5).

The aware consumers internalize the damage and decrease their demand D_1^1. The non-internalized damage incurred by the unaware and concerned

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consumers in proportion $((1-\gamma)\beta)$ should be accounted for in the welfare calculation. This non-internalized damage is represented by the area $0(-E(r))vh$, where h is the consumption of the unaware and concerned consumers with a demand D_1^0 at price P_R. For all concerned consumers, the surplus is $P_R agc$. For the non-concerned consumers in proportion $(1-\beta)$ with a demand D_2, the surplus is given, by the area azA. The overall consumers' surplus (area $P_R agc + azA$) minus the non-internalized damage yields an overall welfare represented by area $P_R agc + azA - 0(-E(r))vh$.

In figure 2, D_L is the demand with the proportion $\gamma = 1$, namely when consumers react in the field exactly as they are supposed to react with well-informed, thoughtful preferences in the lab. In this case, the field leads to similar reactions to the ones calibrated with lab data, which corresponds to a case of perfect label where all the relevant information revealed in the lab is given to consumers in the field. If, after the advisory release, consumers overreact compared to how they would react in the lab, then the demand is given by D_3. There is no more externalized damage and the welfare is given by $P_R(a-\psi)d$ in figure 2.

The combination of tax and advisory is not detailed for space consideration, but can be easily determined by combining both instruments previously described.

4. Lab and Field Experiments on Fish and Methylmercury

The example of this paper considers the methyl-mercury risk coming from fish consumption. Methyl-mercury, an organic form of mercury, is a toxic compound that may alter 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 methyl-mercury. High levels of methyl-mercury occur in long-lived, predatory fish, such as tuna, shark, and swordfish. The regulatory choices to curb this risk are complex since some nutrients in fish are also essential to the health of a developing fetus. More precisely, omega-3 polyunsaturated fatty acids may confer benefits to the fetus and in particular improve infant cognition and cardiovascular health (EFSA, 2004).

In order to manage this risk, several countries have decided to issue specific advisories: the United States at the beginning of 2001 and in 2004 (FDA-EPA, 2004); Canada in 2002 (Health Canada, 2002); the United Kingdom in 2003 (FSA, 2003); Ireland (FSAI, 2004), Australia, and New Zealand in 2004 (FSANZ, 2004). The responsible health or food agencies of these countries have issued an advisory that vulnerable groups (small children, pregnant women, and women of childbearing age) should consume fish but avoid long-lived, predatory fish because of high levels of mercury contamination (EFSA, 2004). At the time of the experiment, conducting two experiments in France was interesting because no major campaign of information about methyl-mercury – via obstetricians, maternity hospitals or booklets – was undertaken by the relevant sanitary authorities. The French authority decided to only post the advisory on the French Food Safety Agency. In the experiment, we simulate this broadcasting in using the information contained in the different advisories mentioned above.

Despite unavoidable differences, both experiments focused on fish consumption, revealed health information on risk (methyl-mercury) and benefit (omega-3) coming from the official consumer advisories and used similar rules of recruitments.

The lab experiment

We first describe the lab protocol before presenting the main results. We conducted the experiment in Dijon, Burgundy's capital, in multiple sessions in January 2006 (see also Marette et al., 2008c). A sample of 115 women was selected using the quota method and is representative of the city's population in terms of age and socio-economic status. We focus on women of childbearing age, namely, women between 18 and 45 years old, as risks posed by methyl-mercury occur mostly during pregnancy and breastfeeding or for young children. The women had to agree to taste both sardines and tuna in order to be selected. 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.

The selection of the specific type of canned tuna and canned sardines was mainly imposed by the availability of products on French grocery shelves in 2005. In a context of a large diversity of cans of different brands and weights on the French market, we selected two cans of the French brand "Connétable" that satisfy numerous common criteria (sauce, can color, weight…). The other reason for selecting tuna and sardines is the considerable difference in contents of mercury and omega-3. Tuna contains high mercury and low omega-3 levels whereas sardines contain high omega-3 and low mercury levels.

The difference in the mercury and omega-3s contents has important consequences for information revealed during the experiment. The description of the message is presented in appendix A. We restricted our attention to one benefit, namely the omega-3 fatty acids, and one risk, namely the methyl-mercury. The message was inspired by data and information provided by health agencies in different countries.

The time schedule of the experiment is presented in appendix A. The choice mechanism focuses on a single endowment point, which means we only use 6 cans of fish I as the initial endowment. Women have the possibility to exchange these 6 cans against varying different quantities of the other product (fish II). The price of a can of fish I was revealed to women before they made their choices. 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 either with 6 cans of tuna or with 6 cans of sardines. 58 participants were endowed with 6 tuna cans and 57 participants were endowed with 6 sardines cans.

Before the revelation of information and after the revelation of information (see appendix A), participants had to indicate their choices for 12 situations. The 12 choice situations were presented on a single sheet of paper (see appendix A). The number of cans of fish II varied from 1 to 12, each corresponding to one situation. For each line, they had to choose between 6 cans of fish I and q_{II} cans of fish 12 with $q_{II} \in \{1,..., 12\}$.

In this experiment, the consumer is endowed with $\overline{q}_I = 6$ cans of fish I at a price $\overline{p}_I$ (revealed before the choice procedure). The experiment provides the switching quantity of Fish II, $\tilde{q}_{II}^j$, the minimal quantity at which the consumer prefers to buy fish II. For $\tilde{q}_{II}^j$, the inequalities $WTP_{II}^j(\tilde{q}_{II}^j - 1) < \overline{p}_I\overline{q}_I^j$ and $WTP_{II}^j\tilde{q}_{II}^j \geq \overline{p}_I\overline{q}_I^j$ are satisfied, where WTP_{II}^j is the unknown WTP for fish II. From the previous inequalities, this value is approximated by

$$WTP_{II}^j = \frac{\overline{p}_I 6}{\tilde{q}_{II}^j} \tag{3}$$

If during the experiment, every $q_{II} \in \{1,...,12\}$ only satisfies $WTP_{II}^j\tilde{q}_{II}^j > \overline{p}_I\overline{q}_I^j$ (namely 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 experiment no $\tilde{q}_{II}^j \in \{1,...,12\}$ is observed for a respondent, we arbitrarily determined a value $\tilde{q}_{II}^j = 13$.

By restricting our attention to tuna only, results are the following. Based on equation (3), we turn to the WTP estimates from the experiment. For tuna, the health information has a statistically significant impact on WTP decreasing because of negative health information. With the precise information revealed to participants the average WTP for a tuna can decreases from to €3.51 to €2.59. This variation will be used in the calibration.

We now present the field experiment that was designed to measure changes in total fish consumption.

The field experiment

We first describe the protocol before presenting the main results (see also Roosen et al., 2009). We conducted a field experiment in Nantes during five months from May to September 2005. A sample of 201 households was recruited. This sample is representative of the city's population in terms of age and socio-economic status. As risks posed by methyl-mercury occur mostly during pregnancy and breastfeeding or for young children, we focus on households with (*i*) at least one woman between 25 and 35 years of age, (*ii*) at least one child under 15 and (*iii*) who consume fish at least twice a week. Consumption of fish more than twice a week is considered as threshold for determining consumers at risk of excessive mercury exposure. The households were told that they were participating in a consumption survey but were not told that the survey was about the health risks associated with food consumption.

A notebook/diary was provided to enable the households to record the fish species and the quantity consumed by all the members. The participants were asked to keep all the receipts for all the fish products they purchased, so that we could check the coherence of the data they recorded in their consumption notebooks. For comparison purposes and in order to control for the seasonal variation in consumption, data on fish consumption was collected for all members of all households under equal conditions in May (see appendix B). The households were then randomized into a treatment (99) and a control group (102). At the beginning of June, the advisory was given to the women in the treatment group (the interviewer read it to the women and left the brochure with them), whereas the members of the control group received no information. The consumption data were collected in June and September for both groups.

The message given to the treatment group was based on advisories provided by health agencies in different countries, as described in section 2 (see appendix B). The brochure defines the group at risk and describes the benefits of fish consumption and the risks associated with methyl-mercury which can impair brain development in fetuses and children. The advisory is structured around three points. Point 1 advises consumers to limit their consumption of fish and seafood products to "2 meals per week".

Point 2 concerns four fish species and advises consumers to restrict their consumption of these particular species of fish to "1 meal per week." As is done in most of national advisories, our advisory makes a distinction between the species of fish that can be consumed once a week and those that should be avoided and mentioned in point 3. The criteria for selecting these species of fish

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were based on the mercury levels. The fish species with a mercury content of 0.2 to 0.4 mg/g were selected as fish species the consumption of which should be limited to "once a week". These fish are grenadier, ling (and blue ling), rock salmon, and canned tuna.

Results from the field are only presented for fish to eat "once a week" where canned tuna represents a very large proportion (84%) of these fish. To formalize our model of a person's choice to buy fish to eat "once a week", we assumed an individual's probability of purchasing these fish estimated via a Probit model with $Prob(Buy\ Fish) = F\left[\hat{\Theta}^T X\right]$ where $F[.]$ is the standard normal cumulative density function with the transposed vector $\hat{\Theta}^T$ of estimated coefficients and X is the vector of independent variables used in the estimation. Table 1 presents the independent variables and the estimation.

The Probit equation shows the parameters influencing the chances of buying fish to eat "once a week". The impact of information is isolated by the variables TREATGROUP.JUNE and TREATGROUP.SEPT coming from the multiplication of the dummy variable TREATGROUP equal to one for the group receiving the advisory and the dummy variable linked to the months JUNE or SEPT (see details in table 1). The last column of table 1 shows that the message reduces significantly the likelihood of consumption, since the parameters linked to variables TREATGROUP.JUNE and TREATGROUP.SEPT are statistically significant. In other words, the advisory significantly matters for deciding whether or not to consume these fish. Eventually, accompanying questionnaires show that only 44% of women recall at the end of June that canned tuna was quoted in the advisory. Such a percentage clearly shows a limited ability to recall species as assumed in the model of section 3.

Table 1. Descriptive of the sample for treatment and control groups and estimates of the probability of purchasing fish to eat "once a week"

	Variable Description	Treat. Mean	Contr Mean	Probit
CONSTANT		1	1	-1.103 (0.754)
TREATGROUP	Dummy variable =1 if in treatment group and zero if not.	1	0	-0.151 (0.171)
JUNE	Dummy variable =1 if observation in June and =0 if not.	0.333	0.333	-0.089 (0.136)
SEPT	Dummy variable =1 if observation in September and =0 if not	0.333	0.333	-0.445*** (0.121)
TREATGROUP.JUNE				-0.941* (0.522)
TREATGROUP.SEPT				-0.851* (0.516)

Table 1 *(continued)*

	Variable Description	Treat. Mean	Contr Mean	Probit
MALE : I_M	Dummy variable =1 if male household head, =0 if not	0.233	0.243	-0.192*** (0.064)
KIDS < 6 : $I_{K<6}$	Dummy variable =1 if child under age of six, =0 if not	0.318	0.328	1.119** (0.546)
KIDS > 6 : $I_{K>6}$	Dummy variable =1 if child over age of six, =0 if not	0.203	0.176	0.853* (0.438)
AGE	Age in years	19.468	19.494	0.128*** (0.034)
AGE^2				-0.002*** (0.001)
SEC1	SEC = Dummy var. indicating socio-economic class defined by profession of male household head (female if no male household head exists). SEC4 is the omitted variable in the estimation. (SEC1= Farmer; SEC2=Handcraft SEC3=clerk (higher position); SEC4 =Intermediate Profession; SEC5=Employee; SEC6=Worker SEC7=Retired; SEC8=Student SEC9=Unempoyed)	0.020	0.000	1.083** (0.494)
SEC2		0.050	0.094	0.300 (0.236)
SEC3		0.218	0.107	-0.214 (0.196)
SEC4		0.240	0.392	
SEC5		0.180	0.117	-0.083 (0.190)
SEC6		0.258	0.270	0.078 0.161
SEC7		0.000	0.000	
SEC8		0.000	0.007	-1.033*** (0.198)
SEC9		0.035	0.012	0.157 (0.511)
INCOME	Categorical variable indicating household revenue	5.494	5.395	-0.015 (0.065)
DEGREE	Categorical variable indicating last degree of female household	3.553	3.722	0.013*** (0.063)
INCOME.TREATGROUP . (JUNE+SEPT)				0.122 (0.100)
DEGREE.TREATGROUP . (JUNE+SEPT)				0.089 (0.095)
No. of observations		1131	1141	2272
R-Square[c]				0.071
No. of correct predictions				1521

Notes : [a] 1 = <600 €, 2 = 600-900 €, 3 = 900-1200 €, 4 = 1200 – 1500 €, 5 = 1500-2300 €, 6 = 2300-3000 €, 7 = 3000 – 6000 €, 8 = more than 8000 €

[b] head 1= no/primary degree, 2= secondary degree, 3= baccalaureat, 4= bac + 2 years, 5 = bac+ more than 2 years

[c] For this probit model we report Efron's R-Square.

Standard errors in parentheses. *,**,*** marks significance at the 10%, 5%,1% level, respectively.

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As the impact of information is statistically significant in lab and field experiments, results are now calibrated in the partial-equilibrium model.

5. The Applied Welfare Analysis under Various Regulatory Scenarios

Using the approach for computing welfare and the results of the experiment described above, we evaluate the welfare variations in agents' surplus that would arise in response to a per-unit tax and/or a label.

The Calibration and the Integration of Experimental Results

The approach relies on a combination of an elasticity of demand coming from time-series economics and values obtained from experiments.[7] The welfare variations are directly given by analytical expressions corresponding to areas described by figures 1-2. We now provide essential details linked to the calibration.

The parameters a and b in (2) can be determined by classical calibration methods. For the baseline scenario without regulation, only the product is offered at price P_R. Recall that almost all consumers are ignorant about mercury since no major campaign of information about methyl-mercury has been decided in France. The overall demand for the product when all consumers are unaware of the damage (with $\gamma = 0$) is given by $Q_R = Q_1^{0D}(p,1) + Q_2^D(p) = (a-p)/b$. Using existing data on the quantity $\hat{Q}_R$ of the product sold over a period, the average price P_R observed over the period, and the direct price elasticity of the demand $\hat{\varepsilon} = (dQ_R/dP_R)(P_R/Q_R)$ obtained from time-series econometric estimates, the calibration leads to estimated values for the demand equal to $1/\tilde{b} = -\hat{\varepsilon}\hat{Q}_R/P_R$ and $\tilde{a} = \tilde{b}\hat{Q}_R + P_R$.

The per-unit damage $E(r)$ is determined by WTP data coming from the lab experiment with values WTP_1^i and WTP_2^i indicating concerned consumer i's WTP before and after the revelation of information. The relative variation in average WTP provides a measure of the inverse demand shift,

[7] See Marette et al. (2010) for considerations regarding the elasticity of demand and robustness of the methodology combining time-series demand and results from lab experiments.

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$\omega = \left[E(WTP_2) - E(WTP_1)\right] / E(WTP_1)$, where *E(.)* denotes the expected value over participants. This relative variation is extrapolated to all concerned consumers.

Without information, we use the initial inverse demand $p_1^{0D}(Q,1-\gamma)$ given by (2) when concerned consumers are unaware with $\gamma = 0$ and represented by D_1 in figure 2. We use the inverse demand for the concerned consumers $p_1^{1D}(Q,\gamma)$ given by (2) when all consumers are informed with $\gamma = 1$ and represented by D_L in figure 2, since all participants are informed in the lab. The relative price variation is equal to the inverse demand shift defined by $[p_1^{1D}(Q,1) - p_1^{0D}(Q,1)] / p_1^{0D}(Q,1) = \omega$. From equation (3), the equality $[p_1^{1D}(Q,1) - p_1^{0D}(Q,1)] / p_1^{0D}(Q,1) = -E(r) / p_1^{0D}(Q,1)$. At the initial equilibrium A in figure 1, the quantity consumed by non-informed consumers is Q_1^A, leading to $p_1^{0D}(Q_1^A,1) = P_R$ and to the estimated value is $E(\tilde{r}) = -\omega P_R$. With $\omega < 0$, the value $E(\tilde{r})$ is positive but negatively impacts the demand $p_1^{1D}(Q,\gamma)$ and the welfare.

For the scenario #2 described in figure 2, the combination of lab and field results determines the proportion γ of consumers internalizing the damage. Recall that the aggregate demands for concerned and informed consumers (with I_i=1) is $Q_1^{1D}(p,\gamma) = Max\left[0, \gamma\beta\left(a - E(r) - p\right)/b\right]$ with $E(r)$ estimated by $E(\tilde{r}) = -\omega P_R$ and the aggregate demand for concerned and non-informed consumers is $Q_1^{0D}(p,1-\gamma) = Max\left[0,(1-\gamma)\beta(a-p)/b\right]$. Based on figure 2, the average shift Δ coming from the advisory is equal to $(Q_1^C - Q_1^A)$, which is equivalent to $\left[Q_1^{1D}(p,\gamma) + Q_1^{0D}(p,1-\gamma)\right] - \left[Q_1^{0D}(p,1)\right] = \Delta$, leading to $\tilde{\gamma} = -\Delta b / [\beta E(\tilde{r})] < 1$. If $\tilde{\gamma} > 1$, consumers overreact and all consumers are aware of the damage. The previous equation changes for being given by $\beta(a-\psi-p)/b - \beta(a-p)/b = \Delta$, leading to $\tilde{\psi} = b\Delta/\beta$ replacing $\tilde{\gamma} > 1$ (see the case with D_3 in figure 2). We now turn to the estimation.

Table 2. Parameters for calibrating the welfare variation

Description	Variable	Value
From time series and observed data		
Consumption of canned tuna in 2008 (kg)[a]	$\hat{Q}^A$	66,707,000
Price of canned tuna in 2008 (€/kg)[a]	P_R	7.4
Own-price elasticity of demand[b]	$\hat{\varepsilon}$	- 0.668
Proportion of women between 20 and 44[c]	β_1	0.173
Proportion of kids (under 6)[c]	β_2	0.086
Proportion of kids (between 7 and 18)[c]	β_3	0.16
Proportion of (male) spouses with a women between 18 and 44 [c]	β_4	0.101
From the lab experiment		
Relative variation in the average WTP by women (also used for kids under and above 6)	ω	- 0.26
From the field experiment		
Relative consumption changes by women between 18 and 44 [d]	δ_1	- 0.02
Relative consumption changes by kids (under 6)[d]	δ_2	- 0.006
Relative consumption changes by kids (between 7 and 18)[d]	δ_3	- 0.008
Relative consumption changes by spouses with women between 18 and 44[d]	δ_4	-0.03

Note: [a] FranceAgriMer (2009).
[b] Authors' estimation.
[c] INSEE (1999): proportions over the French population. Note that the concerned consumers are $\beta_1 + \beta_2 + \beta_3 = \beta$ with β defined for equation (2).
[d] The definition are $\delta_1 = \Delta_1 / [N_W \alpha_W V(0,0,0,0)] = [V(1,0,0,0)/V(0,0,0,0)] - 1$, $\delta_2 = [V(1,1,0,0)/V(0,1,0,0)] - 1$, $\delta_3 = [V(1,0,1,0)/V(0,0,1,0)] - 1$ and $\delta_4 = [V(1,0,0,1)/V(0,0,0,1)] - 1$.

Data necessary for calibrating the welfare are reported in table 2. These data are useful for replicating prices and quantities of tuna sold in 2008 in the French market.

The group of concerned consumers in proportion β and figure 1 is divided in 4 subgroups taken into account in the simulations, since the Probit model of table 1 allows this distinction. We distinguished between the women between 18 and 44, the kids under 6, the kids between 7 and 18 and the spouses of women between 18 and 44.

Table 2 also details some results coming from both experiments. Note that the parameter ω coming from the lab experiment is applied to both women and kids and not to the spouses, since the spouses are not concerned by the methyl-mercury problem. As a consequence, for the spouses, it is assumed that their reaction to the information about methyl-mercury would be zero in the lab with $\omega' = 0$.

The consumption changes linked to the advisory revealed in the field are also computed for the four subgroups. We only consider the variation coming from the information after the first month by focusing on coefficient -0.941 linked to the variable TREATGROUP.JUNE in table 1 and by having the variables JUNE=1 and SEPT=0.[8] The average probability of purchasing the fish with a warning to "eat once a week" is given by $V(TREATGROUP.JUNE, I_{K<6}, I_{K>6}, I_M)$ $= F[-0.941 \times TREATGROUP.JUNE + 1.119 \times I_{K<6} + 0.853 \times I_{K>6} - 0.192 \times I_M +$ $\hat{\Theta}_{other}^T \overline{X}]$, where F[.] is the standard normal cumulative density function used for the Probit estimation. The variable $TREATGROUP$ is equal to one when the advisory is revealed to the treatment group, $JUNE$=1 and $I_{K<6}, I_{K>6}, I_M$ are respectively equal to one if the respective subgroup is considered. The transposed vector $\hat{\Theta}_{other}^T$ contains all the other estimated coefficients in table 1 and $\overline{X}$ is the vector of the average values of the other independent variables used in the estimation (see the combination of two first columns of table 1).

We just detail the determination of the average shift Δ_1 for women (the demonstration is similar for other subgroups). From table 1, the probability of purchasing fish for a woman is given by $V(TREATGROUP.JUNE, 0, 0, 0)$ since the dummy variable equal to one for women is the omitted variable in the estimation. For the subgroup of women, the consumption of tuna over a period can be defined by $N_W \alpha_W V(TREATGROUP.JUNE, 0, 0, 0)$, where N_W is the number of purchase by women between 18 and 45 over the period and α_W is the proportion of tuna among the fish to eat once a week (a vast majority of people are consuming fish once a week). As in figure 2, the consumption variation is defined by $\Delta_1 = N_W \alpha_W [V(1,0,0,0) - V(0,0,0,0)]$. As detailed above, the estimated proportion of women internalizing the damage is $\tilde{\gamma}_1 = -\Delta_1 \tilde{b} / [\beta E(\tilde{r})]$. For facilitating the reading, table 2 only presents the relative variation $\delta_1, \delta_2, \delta_3, \delta_4$ detailed in note d of table 2 (with $\delta_1 = \Delta_1 / [N_W \alpha_W V(0,0,0,0)]$). Note that for the spouses, the variation in the field is $\delta_4 < 0$ due to joint meals in

[8] Long-term effects could be taken into account by using September data with the variable SEPT=1.

family, even if their reaction in the lab is $\omega' = 0$. Except for spouses with women between 18 and 44, the relative variation for the subgroup of non-concerned consumers is $\delta = 0$.

Welfare Impact of Regulatory Tools

Table 3 provides the economic impact of different regulatory tools by presenting welfare variations. These welfare variations (calculated with *Mathematica*) are computed by taking into account the welfare under a given scenario minus the welfare under the baseline scenario, which is defined for the year 2008 under the absence of regulation. Note that taxes are determined in a way that maximizes welfare.

Table 3. **Changes (in value and in percentage) in welfare for different regulatory tools compared to the baseline scenario (without regulation)**

Scenarios	Welfare Variations
Per-Unit Tax (Lab Only)	
Tax Level (€/kg)	$t^* = 0.8$
Welfare Variation (€)	1,956,700 (+0.6%)
Advisory (Lab+Field)	
Welfare Variation (€)	326,089 (+0.1%)
Advisory + Per-Unit Tax (Lab+Field)	
Tax Level (€/kg)	$t^{**} = 0.7$
Welfare Variation (€)	1,831,727 (+0.5%)
Hypothetical Case:	
Only Attentive Consumers, γ =1 (Lab Only)	
Welfare Variation (€)	26,618,813 (+8.4%)

Note: relative variation (%) compared to the baseline scenario in parentheses

In table 3, all welfare variations are positive, which means that the regulation increases welfare. Both instruments have different effects. The advisory does not impose distortions on non-concerned consumers, while the tax internalizes the residual damage of the concerned consumers who would purchase tuna because of their lowest price without knowing the damage linked to them.

The welfare impact of the advisory alone is relatively low compared to the impact of the tax with or without the advisory. Indeed, the advisory has a relatively low impact on consumption of women and kids as shown by δ_1, δ_2 and δ_3 in table 2 and imposes unnecessary consumption reduction δ_4 on spouses who are not concerned by methyl-mercury (with $\omega' = 0$). The consumption variable for spouses is correlated to the consumption variable for other household members.

The welfare with a tax t^* = 0.8€/kg without any information is slightly higher than the welfare with both tax t^{**} = 0.7€/kg and advisory. This tax t^{**} = 0.7€/kg with information would be an extra-burden for the proportion γ of attentive and concerned consumers informed about risks along with non-concerned consumers. The socially optimal tax t^* = 0.8€/kg is distortive since it affects non-concerned consumers, like the spouses and other people in households without women between 18 and 44.

Regarding the welfare maximization, the tax t^* = 0.8€/kg *à la* Pigou without information/advisory is slightly better than the combination of an advisory and a tax t^{**} = 0.7€/kg. As shown by additional simulations, this result is explained by (*i*) the low reaction to the advisory by women ($\delta_1 = -0.02$) and kids and (*ii*) by the fact that spouses are impacted by the advisory even if they are not concerned by methyl-mercury (with δ_4<0 in table 2 and $\omega' = 0$). First, under a hypothetical absence of consumption change for spouses, namely for $\delta_4 = 0$, any relative consumption change $\overline{\delta} < 0$ for women and kids with $\delta_1 = \delta_2 = \delta_3 = \overline{\delta}$ would lead to the systematic selection of the combination of the advisory and the tax t^{***} for maximizing the welfare *(*t^{***} decreasing with $\overline{\delta}$) . Second, with the levels δ_2 δ_3, δ_4 given by table 2, any hypothetical consumption change for women $\tilde{\delta}_1$ with $\tilde{\delta}_1 < -0.06$ would also lead to the selection of the advisory and the tax t^{***} for maximizing the welfare. Compared to the advisory of this field experiment, a more intense information campaign could imply a shift $\tilde{\delta}_1 < -0.06$ and the selection of both instruments. Results of table 3 with an optimal tax t^* = 0.8€/kg without information are specific to our example, with a field experiment showing a decrease in the spouse consumption due to joint meals in family.

The hypothetical case of a "perfect" advisory with only attentive concerned consumers corresponding to $\gamma = 1$ (as given by the lab experiment) would imply a much larger improvement in welfare compared to the tax and/or the advisory (see the last line of table 3). In the field, the advisory is relatively inefficient because of the lack of attentiveness and/or recall by women and the tax has the disadvantage to impose a distortion on non-concerned consumers. This shows the difference between a real situation with imperfect instruments compared to a hypothetical situation where information will be perfectly provided to concerned and attentive consumers. This last result shows that it cannot be taken for granted that a target audience will pay attention to information intended for it.

The welfare variations do not take into account the administrative costs linked to the design and the implementation of regulation. These costs need to be taken into account for complete BCA. Welfare variations presented in table 3 could be compared to administrative costs not taken into account in this study and linked to different instruments for deciding whether or not to implement regulation. If the administrative cost outweighed the highest welfare variation of table 3 equal to €1,956,700, the tax t^* = 0.8€/kg would not be promulgated.

6. Extensions

In order to focus on the main economic mechanisms and to keep the mathematical aspects as simple as possible, the analytical framework and the tools were admittedly simple. In order to fit different problems coming from various contexts, some extensions could be integrated into the model presented here.

Results of table 3 should be interpreted being aware of inherent limits coming from the model and the available information. Robustness of results could/should be presented by altering values of some parameters. In particular, substitution with other fish should be considered for taking into account all indirect effects coming from instruments focusing on tuna and predatory fish (see Marette et al., 2008b).

The analysis could also be refined by considering other consumer subgroups for defining the relevant policy. In the simple model of section 3, we divided the consumers in a proportion $\beta=N_I/N$ of consumers (the women and the kids) a priori concerned by the potential damage and the proportion $(1-\beta) = 1-N_I/N$ not concerned by the potential damage (namely, men and older women). For the subgroup of concerned consumers, we could distinguish between participants reacting a lot to the information during experiments and the one who did not react at all in the lab (see the note 3) and the field.

Another important dimension would be to distinguish between participants eating (or liking) a lot of fish and other participants eating fish occasionally (see Roosen et al., 2007). The level of detail in each experiment was insufficient for making such a distinction. Indeed, our lab experiment only collected frequencies of consumptions based on a simple question at the beginning of the experiment, with a relatively poor econometric link between the declared frequency and the WTP shift following the revelation of information. Numerous consumers with a low consumption frequency significantly decrease their WTP. Moreover, from the field experiment, the relationship between the variation of consumption after the advisory and the initial consumption in May was significant but relatively small. These types of refinements could be introduced in a complete BCA with specific calibrated values $E(\tilde{r}_j) = -\omega_j P_R$ and $\tilde{\gamma}_j = -\Delta_j b / [\beta E(\tilde{r}_j)]$ determined for each subgroup j. Note that all these new subgroups' surpluses would be aggregated for determining the welfare, as we made for the five subgroups including the non-concerned consumers leading to table 3. The aggregation process would level off part of differences between welfare estimates with different subgroups.

A dynamic analysis could study the possible long-lasting effects of warning/messages (see note 8). Both types of experiment used in this paper are obviously limited regarding the measurement of impacts over several years. Long lasting effects and complex consumers' reactions can be studied with retail data and natural experiments that result from situations for which the assignment of intervention has been made by a regulator or by "nature" (see an econometric analysis of the US policy regarding the methyl-mercury by Shimshack et al., 2007). Eventually, the supply side could be also developed with increasing supply curves coming from firms/fisheries with decreasing returns to scale. In this case, equilibrium price would vary with policies and the effects could be carefully studied.

Moreover, other instruments could be envisioned regarding the tuna example. In particular, a minimum-quality standard eliminating fish with a high level of contamination for tuna or a label posted on the package of contaminated fish could be studied.[9] Our paper shows that medical advisories/warnings directed toward pregnant women or women of childbearing age (via brochures or Internet) are not a panacea and that alternative tools might be considered. Mandatory labels and simple placards posted on products in the supermarkets or on menus in restaurants can be an alternative to medical brochures. A simple warning for pregnant women would correspond to the finding that a simple message is more efficient compared to long messages with complex and scientific information (Wansink et al., 2004).

7. Conclusion

Regulatory authorities often face intense pressures to act on controversial or uncertain topics. However, the toolkit of regulatory options is large and the choice among the alternatives difficult. An important criterion is the economic efficiency of the different options. In this paper, we focused on the welfare effects of two policy instruments (per-unit tax and/or advisory) and showed how to link consumers' WTP estimates coming from both experiments to welfare effects of regulatory scenarios. Experimental results provide a useful basis to anticipate consumers' reactions and allow regulatory authorities to consider different options in terms of their costs and benefits including market reactions.

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[9] Disdier and Marette (2010) use results from a lab experiment for calibrating the damage with results from a natural experiment linked to the reinforcement of a minimum-quality standard for limiting anti-biotic residues for crustaceans in the European Union.

Despite the limitations, the methodology can be replicated for helping the public debate, when internal and external validity of experiments are "relatively" assured for the same types of good (see section 2). With food, measures coming from the lab seem reliable for BCA, even if no definitive conclusion can be taken.

Despite the limitations, our results clearly show the impact of different instruments. This methodology supports public debates about the best way to promote an efficient policy. Different regulatory scenarios may be tested *ex ante*, and the methodology renders lab and field experiments useful for policy analysis, which is an important challenge for experimental economics.

APPENDIX A: The timing and the message of the lab experiment

During the experimental session, women were asked to assess a choice between two types of fish. Since women were endowed with either tuna or sardines, we refer to the fish of endowment as fish I and to the other as fish II. Overall, 58 women participated in the treatment endowment tuna (group 1) and 57 in the treatment endowment sardines (group 2). The assignment of a convened group of consumers to either treatment was made at random. The session was divided into eight stages.[10] The exact transcript of the experiment is available on request to the authors.

(1) Participating women read some general instructions and signed a form stipulating that they accept to 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 boxes of both tuna and sardines (see appendix A).[11] Then the can price of the endowed fish I, $\overline{p}_I$, 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 fish and to give a hedonic rating indicating their preference for tuna or sardines.

(5) The choice procedure was explained and the choice experiment was conducted before and after receiving the health information.

The choice sheet was the following. For each line, participants had to choose between 6 cans of sardines and q_{II} cans of tuna 12 with $q_{II} \in \{1,..., 12\}$.

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

[11] Note that the nutritional information presented in appendix A is not posted on the cans, since there is no mandatory nutrition information required in France.

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

The message for the lab experiment was the following:

Fish is important for the dietary balance. 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. (Endowment tuna)
Sardines contain six-fold more omega-3 fatty acids than tuna. (Endowment sardines)
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 to eat fish at least twice a week.
Fish contains methyl-mercury (organic form of mercury) naturally present in water and coming from industrial pollutions. All fish contain traces of methyl-mercury. By accumulation, larger fish that have lived longer have the highest level of methyl-mercury.
Tuna contains four-fold more methyl-mercury than sardines. (Endowment tuna)
Sardines contain four-fold less methyl-mercury than tuna. (Endowment sardines)
The mercury effects on health have been shown by several medical studies. The results of these studies show a lack in the brain development for the foetus and the children exposed to the mercury. Public health authorities advise pregnant women, childbearing women and young children to avoid the consumption of predatory fish such as tuna.

(6) Subjects received a second set of plates for tasting the products. They had two minutes to taste both fish and to give a hedonic rating indicating their preference for tuna or sardines.

(7) Participants replied to a short questionnaire on their choices done.

(8) The experiment concluded by randomly selecting the products to be remitted to participants based on the selected choices. Participants also received 10 euros of indemnity and a brochure explaining the risks linked to the methyl-mercury.

APPENDIX B: The timing and the message of the field experiment

The design of the experiment was on several steps:

(1) At the beginning of the first month (May), the notebook and the method for collecting information were explained. The interviewer filled in a questionnaire concerning socio-demographic characteristics and perception of food safety issues.

(2) At the end of the first month, while a second visit, the interviewer collected and checked the notebook with the recording of fish consumption. Then, for the treatment group only, the advisory (detailed in the next section) was read and given to the woman.

(3) At the end of the second month (June) the interviewer collected and checked the notebook with the recording of fish consumption. Then, for the treatment group only, an interview was done about participant's understanding of information received in the brochure and choices made.

(4) Break of two months in the recording of fish consumption. At the end of the fourth month (August), during a phone follow-up, participants were reminded that the notebook had to be filled in for the following month

(5) At the end of the fifth month (September) interviewer collected and checked the notebook with the recording of fish consumption. Then, for the treatment group only, an interview was done about participant's understanding of information received in the brochure and choices made. The brochure given to consumers in May was the following.

The Message (Translation) What You Need to Know About Mercury in Fish and Sea Products *Recommendations for* **Women Who Might Become Pregnant** **Pregnant Women** **Nursing Mothers** **Young Children** Page 1 of the brochure	**Mercury and health concerns** **Several medical studies have led the European Commission and public health authorities from numerous countries (including France, the United States, and New Zealand) to set up recommendations regarding fish consumption.** **Fish is important for a balanced diet. Fish is a good source of proteins, vitamins, and minerals. Fish content is high in omega-3 fatty acids and low in saturated fat.** **Regular consumption of fish helps to reduce the risks of cardiovascular diseases and it contributes to brain development and growth of children.** **However, fish contains methyl-mercury (an organic form of mercury) naturally present in water and coming from industrial pollution. All fish contain traces of methyl-mercury. Through accumulation, larger fish that have lived longer have the highest level of methyl-mercury.** **Effects of mercury on health have been shown in several medical studies. The results of these studies show a lack of brain development in the fetus and in children exposed to mercury.** **Consumers always benefit from the nutritional effects of fish. However, pregnant women and young children have to restrict their consumption of most contaminated species.** Page 2 of the brochure

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Recommendation for **Women Who Might Become Pregnant** **Pregnant Women** **Nursing Mothers** **Young Children (under 6)** **1. Limit to 2 meals[1] per week fish and sea products.** **2. So, when choosing the 2 meals, restrict to 1 meal per week the consumption of:** **- canned tuna** **- or rock salmon (dogfish)** **- or grenadier** **- or ling (blue ling)** **3. Do not eat :** **- fresh tuna** **- shark** **- swordfish** **- marlin** **- grouper** **These recommendations are based on both French consumption habits and methyl-mercury contamination of fish and sea products sold in France.** [1] An average portion per meal is equal to 150 g for an adult and 100 g for a young child.For canned tuna, an average portion is equal to 60 g for an adult (a small can) and to 30 g for a young child. Page 3 of the brochure	**For additional information, contact** **Email** **Phone number** Page 4 of the brochure

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