Tax, Subsidy, and/or Information for Health: An Example from Fish Consumption

Stéphan Marette, Jutta Roosen, and Sandrine Blanchemanche

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Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Stephan Marette is a research fellow at the Institut National de la Recherche Agronomique (INRA), France. He was a visiting scholar at CARD when research for this paper was conducted. Jutta Roosen is with the Department of Food Economics and Consumption Studies, University of Kiel, Germany. Sandrine Blanchemance is with the Met@risk unit of INRA.

Questions or comments about the contents of this paper should be directed to Stéphan Marette, UMR Economie Publique INRA-AgroParisTech, BP01, 78850 Grignon, France; E-mail: marette@agroparistech.fr

Abstract

A calibrated model is used to determine the welfare impacts of various regulatory instruments for improving health. The results of a lab experiment are integrated in a partial equilibrium model representing demands for two kinds of fish, one with higher nutritional benefits (canned sardines) and one with higher contamination risks (canned tuna) in France. In the laboratory, information about health effects leads to a statistically significant decrease (increase) in the willingness to pay for tuna (sardines). Simulations with the laboratory results show that, for most cases, a per-unit tax on tuna and a per-unit subsidy on sardines without any information revealed to consumers lead to the highest welfare, because both the tax and subsidy directly internalize health characteristics. The information policy combined with a per-unit tax on tuna and a per-unit subsidy on sardines is socially profitable only if a large proportion of consumers (greater than 95%) receives health information.

Keywords: health, information, regulation, taxation.

1. Introduction

Food is a major contributor to health. “Eating well” always emerges as one of the top recommendations for reducing risks of heart disease, diabetes, cancer, osteoporosis, and other medical conditions, as is clearly shown on the famous Harvard website, *Your Disease Risk*.[1] There are intense debates in Western countries about the best way to promote healthy eating for reducing risks, with a particular focus on obesity. Nutritional advice is often seen as too limited in its impact to reverse current trends in nutrition-related diseases. Numerous public health experts and politicians in many countries have proposed imposing a tax on fat/sugar or offering a subsidy on “thin” foods such as fruits and vegetables (see Jacobson and Brownell, 2000). Other experts (see Kuchler et al., 2005) note that taxes raise revenues that could be used for educational programs or advertising for healthy products. The debate is surrounded by a lot of uncertainty about choices among regulatory tools and also about the way to finance them.

To shed light on this regulatory question, we restrict our attention to fish consumption. The safety and nutrition of fish consumption have become an increasing public health concern in recent years. Fish consumption involves a balance between benefits such as omega-3 fatty acids and risks such as methylmercury. There are large differences among fish species regarding their health-promoting content. Information is a classical instrument for emphasizing health benefits and risks, but it is often doomed to failure because of consumers’ confusion about different species or their lack of attention to health messages. A tax-subsidy program may complement an information policy and it may also finance it. The example of fish consumption was chosen because fish has the advantage of being a main source of omega-3 and of methylmercury, which facilitates regulatory simulations because of separability from other products in the regulatory decision. In this sense, issues involved in the regulation of fish differ a lot from questions surrounding obesity. Obesity involves numerous goods and nutrients (see Kuchler et al., 2005), which makes it very difficult to determine an optimal regulatory program entailing taxes, subsidies, and/or information revealed to consumers.

The purpose of this paper is to evaluate the impact of a health taxation/subsidy program and/or information on fish consumption and consumers' welfare. For determining the optimal program, we combine the results of a laboratory experiment with a partial equilibrium model. We conducted a lab experiment in Dijon, France, in order to focus on choices between canned sardines and canned tuna by taking into account revealed information about methylmercury and omega-3.

The partial equilibrium model is calibrated for representing demands of canned sardines and tuna in France. Linear demand opens the possibility of computing the fiscal budgets related to regulation in the fish market. Both a per-unit tax imposed on tuna because of methylmercury, and a per-unit subsidy supplied for sardines because of omega-3 are selected to maximize welfare by taking into account a costly information policy.

Different options regarding the fiscal budget linked to the regulatory tools are considered in the study, whether or not the opportunity to earmark tax revenues for subsidizing healthy fish and/or information is justified. Under a first fiscal program, the budget linked to fish regulation is not balanced (it is complemented by a lump-sum transfer provided by the rest of the economy and taken into account in the welfare assessment), while under the second fiscal program, the budget linked to fish regulation is balanced. For this second program, balancing a tax, subsidy, and the cost of information about fish, simulations are essential because simple analytical solutions do not exist.

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[1] See http://www.yourdiseaserisk.harvard.edu/ (available, April 2007).

The results are as follows. The changes in willingness to pay (WTP) in the lab experiment for canned tuna and canned sardines are statistically significant after the revelation of health information. Information about methylmercury and omega-3 leads to a WTP decrease for tuna and to a WTP increase for sardines. Since the impact of information is statistically significant, it is possible to use these results for evaluating different policy options in the calibrated model.

The simulations of regulatory instruments then show that with relatively few consumers receiving health information, a per-unit tax on tuna and a per-unit subsidy on sardines without information are welfare superior, because both the tax and subsidy internalize health characteristics not taken into account by unaware consumers. Combining a tax on tuna and a subsidy on sardines with an information policy is socially preferable if a large proportion, namely, greater than 95%, of consumers can receive the health information, and if the cost of information is not too large. When all consumers receive the information, no tax/subsidy is imposed if the regulatory budget for fish does not need to be balanced, while the information policy is combined with a tax on both tuna and sardines for financing when this budget has to be balanced. Whatever the instrument selected, the welfare resulting from the program that does not balance the regulatory budget for fish is very close to the one that balances the regulatory budget for fish. This implies that a regulation on a fish market may be autonomously implemented without relying on alternative sources of finance (as a lump-sum transfer provided by the rest of the economy).

Despite various limitations coming from the experiment and the calibration, the combinations of tax, subsidy, and information computed in this study are informative simulations that provide credible suggestions for the choice of instruments by a regulator aiming at welfare maximization. We consider the results credible given (*i*) the statistical significance of the consumption changes following the revelation of information in the experiment, and (*ii*) the relatively low values of price elasticities for tuna and sardines used for calibration, entailing relatively low variations of linear demand curves coming from price changes due to regulatory choices. Hence, the demand variations are relatively close to variations coming from the ones defined with a calibrated model based on a non-linear demand curve.

This paper contributes to various aspects of regulatory debates. From a methodological point of view our paper adds to the literature by directly taking into account experimental results from a lab for simulating various regulatory options.[2] This methodology supports public debates about the best way to promote healthy products. Despite limitations, different regulatory scenarios may be tested *ex ante,* and the methodology renders lab experiments useful for policy analysis, which is an important challenge for experimental economics (see List, 2007).

From a theoretical point of view, we add to the literature by considering a combination of regulatory instruments often overlooked (see Teisl and Roe, 1998). The literature is lacking studies about the combination of information and tax/subsidy programs. In our paper, the role of a Pigouvian tax is twofold, since it limits a negative damage linked to a risk and it also contributes, in part or in full, to financing other regulatory instruments. This differs from previous contributions on the best way to finance regulation, as, for instance, in Marette and Crespi (2005), which does not consider the Pigouvian tax.

Our paper also adds to the debate on regulatory approaches in health policy.[3] It differs from previous contributions that study the effects of taxation or subsidization of products for dealing

[2] The experimental procedures differs from previous contributions studying willingness to pay (i.e., how much consumers are ready to pay for a given product) with auctions *à la* Vickrey (1961) for a single product, since this paper uses an alternative choice procedure eliciting the propensity to substitute two products for each other (for how much of an alternative product consumers are ready to exchange a given quantity of endowed products). The methodology of this paper is tailored to nutrition issues, in which policy aims at substituting healthy products for risky products.

[3] Regarding the methylmercury problem, our paper differs from those of Gayer and Hahn (2005, 2006), which focus on environmental regulations capping power plant emissions of mercury. Our paper looks at a different step in the chain of mercury contamination by focusing on the fish market.

with obesity problems. Papers in that area focus on either a fat tax (Jacobson and Brownell, 2000; Kuchler et al., 2005; and Chouinard et al., 2007) or a thin subsidy (Cash et al., 2006 and Gustavsen and Rickertsen, 2006), while our paper focuses on both a tax and a subsidy combined with an information program. Including both a tax and a subsidy shows the importance of considering both risks and benefits coming from a product in determining regulation. Moreover, we pay specific attention to the budget constraint for the regulator. In comparison to existing papers on food taxes/subsidies, we go further by computing an optimal tax/subsidy program maximizing welfare. This is possible because we have from the lab an estimate of the cost of ignorance, which is absent in other studies that rely on more normative approaches to achieve results consistent with nutrition recommendations.

The paper is organized as follows. Section 2 introduces the debate about fish consumption and regulation. Section 3 focuses on a simple model taking into account the instruments, while section 4 details the lab experiment. The model calibration of the canned fish market in France and the simulations of the regulation are presented in section 5. Conclusions are discussed in section 6.

2. The Regulatory Debate over Health and Fish Consumption

Fish consumption involves a balance between benefits (mainly coming from omega-3s) and risks (mainly coming from methylmercury), and there are large differences among fish species in terms of their health-promoting content (see table 1).

First, omega-3 polyunsaturated fatty acids confer benefits to the fetus such as infant cognition and improvement in cardiovascular health (EFSA, 2005, p. 1). A recent *Lancet* article reinforced the momentum for benefits linked to omega-3s by suggesting that fish consumption is crucial during pregnancy (see Hibblen, 2007). Adults also benefit from omega-3s through a significant reduction in risks of cardiovascular diseases for those who consume these fatty acids (Sidhu, 2003). Fatty fish (like salmon, sardines, or mackerel) are particularly rich in omega-3 (see table 1).

Second, methylmercury, an organic form of mercury, is a toxic compound that alters fetal brain development when there is significant prenatal exposure (EFSA, 2005). Children of women who consume large amounts of fish before and 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) (see table 1).

The regulatory choice of how to manage this risk and/or to promote this benefit is complex because of the species heterogeneity regarding the omega-3 and methylmercury contents. In other words, promoting fish consumption and limiting methylmercury contamination should be the regulatory target. For the mercury problem, there are four main ways for a regulator to intervene, namely, (1) to regulate the mercury emissions from power plants; (2) to regulate the methylmercury content of fish via a minimum quality/safety standard; (3) to inform the concerned public via advertising, health warnings or labels (posted on products or in restaurants); and (4) to select a tax/subsidy program for limiting consumption of dangerous foods and promoting the consumption of healthy foods. Beales et al. (1981) mention the importance of combining instruments for limiting the potential distortions/costs coming from each instrument. Regulatory instruments need some monitoring and enforcement capacity. We briefly review advantages and inconveniences of these three instruments for managing the risks of methylmercury.

First, the regulator may try to cap the emission of mercury by industry. Mercury comes from both industry and natural sources (from volcanoes for instance). The emitted mercury is deposited in freshwater, where it becomes methylmercury, which then contaminates fish. In 2000, the United States decided to regulate mercury emissions from power plants due to coal burning. Gayer and Hahn (2005, 2006) show that the costs of this regulation outweigh the benefits. In other words, the regulation imposes a large cost on firms while the impact on fish contamination and related child IQ scores are very limited, because of weak evidence on the chain of causality from power plants to fetus absorption due to fish consumption (see figure 3, p. 303, in Gayer and Hahn, 2006).[4] These findings should lead regulators to favor intervention in fish consumption for reaching regulatory efficiency.

The second instrument consists in applying a minimum quality/safety standard that determines a maximum level of methylmercury in fish with which all fisheries should comply. Setting standards can be an efficient policy tool because it simply eliminates those products that do not comply with certain minimum requirements. Under existing European Regulation No. 78/2005 (EC, 2005), the maximum level of mercury is 0.5 mg/kg for fish, while the maximum level of mercury is 1 mg/kg for *predatory* fish. Reinforcing the standard with a decrease of the threshold lower than 0.5 mg/kg for all fish would be very costly to implement, since numerous fish with a mercury level above the new threshold would be withdrawn from the market. Moreover, the testing procedure, as in the large-scale testing system developed by Micro Analytical Systems Inc. (Adamy, 2005), would also be costly for fisheries.

The third instrument is the revelation of information (via generic advertising, educational programs, press release, brochures at hospitals, labeling, etc.). Several OECD countries,

[4] The European Commission has recently proposed legislation to ban all European Union exports of mercury beginning in 2011, mainly coming from a Spanish state-owned firm (EC, 2006). The export ban is expected to

including the United States since 2001 (EPA, 2004), have decided to broadcast specific advisories stipulating 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 because of high levels of methylmercury contamination. The broadcast and information programs, which vary among countries, generally use the Internet, mass media, or brochures distributed by gynecologists and obstetricians. The 2001 US advisory was found to have its intended effect, as pregnant women reduced their consumption of fish (Oken et al., 2003 and Shimshack et al., 2007).

However, the US advisory on methylmercury raised strong criticisms by doctors 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 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." All the messages explicitly mention the benefits of fish consumption while they differ about the details linked to the benefits, since omega-3 or fatty fish rich in omega-3 (like salmon, sardines, and mackerel) are not always mentioned. For omega-3 benefits, advertising and information campaigns by cardiologists/hospitals or by associations like the *American Heart Association* may influence both women and men. The main problem with warnings[5] or recommendations about fish is the difficulty of species recollection. Roosen et al. (2007) show that during a field experiment consumers imperfectly recalled fish species quoted in a warning for mercury.

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reduce global supply and emissions of the heavy metal into the environment.

[5] Mandatory labeling signaling mercury could also be posted on canned tuna. This type of label may compete with environmental labels such as "Dolphin-Safe" information also posted on canned tuna (see Teisl et al., 2002).

The fourth instrument is taxation for fish with high mercury content and subsidization for fish with high omega-3 content.[6] There are many inconveniences linked to the tax/subsidy but they may be complementary to previous instruments. First, a tax is generally preferable to a subsidy because the tax generates revenues for the government, whereas the subsidy requires the government to raise revenues elsewhere. However, tax revenues on dangerous fish could be earmarked for subsidizing healthy fish.

The earmarking presents drawbacks since "there is no general reason … that the revenue raised by the efficient corrective tax on some polluting activity will exactly equal the efficient level of expenditure on mitigating the harm suffered" (Brett and Keen, 2000, p. 316).[7] Earmarking may be one way to bypass politically weakness (Brett and Keen, 2000) or to get large political support by consumers/voters (Buchanan, 1969, and Jacobson and Brownell, 2000). A tax linked to high content of methylmercury is likely to be "regressive," since the resulting price distortion would negatively affect a surplus of consumers who are not concerned (namely, households without kids) or who are already informed about this problem.

While the link between food and health raises many questions, we focus on one central economic aspect of the debate: the link between information and a tax/subsidy program. A simple model is proposed for measuring the impact of a tax, a subsidy, and/or information on

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[6] The liability of producers or regulators could also arise. One aspect of the recent debate in the US is on whether tuna canners should be held liable for lack of information about risks. Even if consumers may have difficulties either knowing or proving that firms are responsible for a sanitary problem, firms may be liable for misrepresentation. There have been lawsuits filed against tuna canners in California for lack of information regarding mercury (Kinsman, 2004), but these have thus far been unsuccessful for plaintiffs. For instance, a proposal for mandatory labeling on canned tuna regarding mercury was dismissed by a court in California in 2006 after intense lobbying by the canned tuna industry (Waldman, 2006).

[7] A tax/subsidy program raises the issue of the "double dividend," since a tax (or a subsidy) not only improves safety/environment but also reduces (or increases) the other costs of the tax system in particular on the labor market (see Parry, 1995 and 1998, and Brett and Keen, 2000, for details).

consumer reaction and market mechanisms (alternative assumptions will be discussed at the end of the paper).[8] We now turn to the simple model.

3. A Simple Theoretical Model

We use a simple model that will be calibrated to French data. We combined Spence's (1976) quasilinear utility function with the approach by Polinsky and Rogerson (1983) for the treatment of 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 4).[9] The utility function of a consumer *k={1,…,K}* concerned by the revealed information is

$$U_k(x_{tk}, x_{sk}, w_k) = \alpha_t x_{tk} - \beta_t x_{tk}^2/2 + \alpha_s x_{sk} - \beta_s x_{sk}^2/2 - \gamma x_{tk} x_{sk} + I(-r_{tk} x_{tk} + h_{sk} x_{sk}) + w_k , \qquad (1)$$

subject to $x_{tk}, x_{tk} \geq 0$ and where w_k is the numeraire good; $\alpha_t x_{tk} - \beta_t x_{tk}^2/2$ (respectively, $\alpha_s x_{sk} - \beta_s x_{sk}^2/2$) is the immediate satisfaction from consuming a quantity x_{tk} of tuna (respectively, x_{sk} of sardines). The parameter γ describes the degree of substitutability between the two products with $\gamma < Min[\beta_t, \beta_s]$ for concavity. The parameter *I* represents the information context. If no information has been revealed then *I*=0. Conversely, *I*=1 means that the subject received information. The health risk (or benefit) for consumer *k* associated with the

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[8] For simplicity, we only consider a tax on canned tuna (because of a relatively high content in methylmercury) and a subsidy on sardines (because of a relatively high content in omega-3). For simplicity, we abstract from the issue of the "double dividend" on other markets as the labor market (see Parry, 1998 and Brett and Keen, 2000, for details). Instead, we focus on the use of tax income for a subsidy and/or financing the information to consumers. We also abstract from firms' market power in the supply chain for simplifying the tax/subsidy program without any initial price distortion that could come from market power (see Calabresi, 1961, or Buchanan, 1969).

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

consumption of tuna (sardines) 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 is h_{sk}.

The maximization of (6) under the budget constraint $p_t x_{tk} + p_s x_{sk} + w_k = y_k$, where y_k denotes the income of person *k*, leads to the following inverse demand function for tuna and sardines:

$$\begin{cases} p_t = \alpha_t - \beta_t x_{tk} - \gamma x_{sk} - I.r_{tk} \\ p_s = \alpha_s - \beta_s x_{sk} - \gamma x_{tk} + I.h_{sk} \end{cases} \qquad (2)$$

where the period denotes multiplication. After the revelation of information (*I*=1), a risk valuation r_{tk} reduces the demand for tuna while a benefit valuation h_{sk} leads to a demand increase for sardines, compared to an initial situation without information (*I*=0). Graphically speaking, the demand curve for tuna shifts downward, whereas the demand curve for sardines shifts upward. We consider both these shifts in the estimation of welfare change. By inverting (7), we obtain consumer *k*'s demand for tuna and sardines:

$$\begin{cases} \overline{x_{tk}}(I, p_t, p_s) = \dfrac{\alpha_t \beta_s - \alpha_s \gamma - \beta_s p_t + \gamma p_s - I(\beta_s r_{tk} + \gamma h_{sk})}{\beta_s \beta_t - \gamma^2} \\ \overline{x_{sk}}(I, p_t, p_s) = \dfrac{\alpha_s \beta_t - \alpha_t \gamma - \beta_t p_s + \gamma p_t + I(\gamma r_{tk} + \beta_t h_{sk})}{\beta_s \beta_t - \gamma^2} \end{cases}. \qquad (3)$$

For a consumer receiving the information, health values are internalized via information, and the surplus is $U_k(p_t, p_s, 1) = U_k\left(\overline{x_{tk}}(1, p_t, p_s), \overline{x_{sk}}(1, p_t, p_s), \overline{w_{k1}}\right)$, with $\overline{w_{k1}} = y_k - p_t \overline{x_{tk}}(1, p_t, p_s) - p_s \overline{x_{sk}}(1, p_t, p_s)$. For a consumer receiving no information, the surplus is $U_k(p_t, p_s, 0) = U_k\left(\overline{x_{tk}}(0, p_t, p_s), \overline{x_{sk}}(0, p_t, p_s), \overline{w_{k0}}\right)$ with $\overline{w_{k0}} = y_k - p_t \overline{x_{tk}}(0, p_t, p_s) - p_s \overline{x_{sk}}(0, p_t, p_s)$. For them, the cost of ignorance linked to the absence of health awareness is $E_k = -r_{tk}\overline{x_{tk}}(0, p_t, p_s) + h_{sk}\overline{x_{sk}}(0, p_t, p_s)$, which is not internalized via the demand. When k_1 consumers are aware of the nutrition characteristics (via the health policy) and k_0 consumers are unaware (with $K = k_1 + k_0$), the overall welfare is

$$W(p_t, p_s, k_1) = \sum_{k=1}^{k_1} U_k\left(p_t, p_s, 1\right) + \sum_{k=k_1+1}^{K}\left(U_k\left(p_t, p_s, 0\right) + E_k\right). \tag{4}$$

We now turn to a description of the regulatory tools. The regulator may choose an information/education policy (via hospital, maternity ward, etc.) that could reach k_1 consumers among the overall *K* consumers at a cost *C*, or not informing. The regulator may also impose a tax/subsidy program, namely, a per-unit tax t_t on tuna and a per-unit subsidy s_s on sardines. Note that a negative s_s corresponds to a tax. For simplicity, we assume that the price variation comes only from the tax/subsidy, which means that initial prices before regulation are equal to constant marginal costs (under a simplifying assumption of constant returns to scale).

For determining the budget constraint, recall that the selection of an information policy (*I*=1) reaches k_1 consumers. By using (3), the regulatory budget linked to fish is

$$\begin{aligned} B(t_t, s_s, I.C) = \sum_{k=1}^{k_1} &\begin{bmatrix} t_t\left(I\overline{x_{tk}}(1, p_t + t_t, p_s - s_s) + (1-I)\overline{x_{tk}}(0, p_t + t_t, p_s - s_s)\right) \\ -s_s\left(I\overline{x_{sk}}(1, p_t + t_t, p_s - s_s) + (1-I)\overline{x_{sk}}(0, p_t + t_t, p_s - s_s)\right) \end{bmatrix} \\ &+ \sum_{k=k_1+1}^{K}\left(t_t\overline{x_{tk}}(0, p_t + t_t, p_s - s_s) - s_s\overline{x_{tk}}(0, p_t + t_t, p_s - s_s)\right) - I.C. \end{aligned} \tag{5}$$

We will compare two types of fiscal programs including a tax, a subsidy, and the cost of information. The fiscal program 1 will maximize the regulatory program without balancing the budget linked to the regulation on the fish market. In other words, the fiscal deficit $B(t_t, s_s, I.C) < 0$ (or surplus $B(t_t, s_s, I.C) > 0$) is financed by a lump-sum tax (or leads to a lump-sum transfer) accounted for in the overall welfare.[10] This may correspond to a transfer coming from a more general health policy decided by a state. This program is

$$\underset{t_t,s_s,I}{Max} \quad W(p_t+t_t, p_s-s_s, I.k_1)+B(t_t,s_s,I.C). \qquad (6)$$

The solution of this program is

$$\begin{cases} t_t^* = \dfrac{(1-I)\sum_{k=1}^{k_1} r_{tk} + \sum_{k=k_1+1}^{K} r_{tk}}{K} \\ s_s^* = \dfrac{(1-I)\sum_{k=1}^{k_1} h_{tk} + \sum_{k=k_1+1}^{K} h_{tk}}{K} \end{cases}, \qquad (7)$$

where information policy I is determined by the welfare comparison between $W(p_t+t_t^*, p_s-s_s^*, k_1)+B(t_t^*,s_s^*,C)$ and $W(p_t+t_t^*, p_s-s_s^*, 0)+B(t_t^*,s_s^*,0)$. The budget constraint $B(t_t^*,s_s^*,I.C)$ may be positive or negative depending on the relative values of per-unit benefits and risks.

Absent information ($I=0$), the values given by (7) correspond to the "classical" Pigouvian tax/subsidy and equal the marginal benefit/cost of the health attribute. This value is equal to the average benefit/cost over consumers since the individual health risk and benefit $-r_{tk}x_{tk}$ and $h_{sk}x_{sk}$ in equation (1) are linear functions of quantities under the specification given by Polinsky and Rogerson (1983).

An information policy (I=1) leads to a reduction of the values given in (7). A tax is a burden for consumers who are already informed or not concerned by the mercury. An information policy may fail to reach consumers but it does not impose regressive distortions on consumers' welfare

[10] Because prices are equal to constant marginal costs (under a simplifying assumption of constant returns to scale), the possibility to tax producers via a fixed fee (that is not passed on to consumers via the price) is not considered (see Marette and Crespi, 2005) for such an extension.

as taxation. Note that when $k_1 = K$ with *I*=1, then the optimal program defined by (7) is $t_t^* = s_s^* = 0$, since all the health characteristics are internalized in demands via the information policy reaching all consumers.

The fiscal program 2 will maximize the regulatory program with a balanced budget linked to the regulation on the fish market.[11] In other words, the taxes raised on the fish market should completely finance spending coming from providing the subsidy and information. The program is

$$\begin{cases} \underset{t_t, s_s, I}{Max} \quad W(p_t + t_t, p_s - s_s, I.k_1) \\ \qquad s.t. \quad B(t_t, s_s, I.C) = 0 \end{cases} . \tag{8}$$

There is no direct solution (section 5 will provide estimations with the calibrated model). Note that if t_t^*, s_s^* given by (7) for program 1 leads to $B(t_t^*, s_s^*, I.C) < 0$, then the program t_t^{**}, s_s^{**} maximizing (8) is such that $B(t_t^{**}, s_s^{**}, I.C) = 0$. In this case, with an information policy (*I=1), s_s^{**}* is positive (a subsidy) for a relatively low k_1 for increasing sardines consumption and it may be negative (a tax) for a k_1 close to K for financing the cost of advertising *C*.

Before presenting the simulations based on the calibrated model, we now present results from the lab experiment that will give average values of the per-unit risk, r_{tk}, and the per-unit health benefit, h_{sk}.

[11] A public board dedicated to fish could manage such a program. In France, the OFIMER (Office National Interprofessionnel des Produits de la Mer et de L'Aquaculture) is a public board in charge of fish market (see http://www.ofimer.fr/Pages/Accueil/1Accueil2004.html, accessed April 2007). It is in charge of a budget for product promotion, scientific studies, statistical studies, etc., financed by taxes paid by fisheries.

4. The Lab Experiment

We first detail the protocol before presenting the main results. The French situation is interesting because no major diffusion of information has been decided upon yet for methylmercury/omega-3. Some warnings, mainly for professionals, have been posted on the website of the Agence Française de Sécurité Sanitaire des Aliments, the French food safety agency (AFSSA, 2002 and 2004). No major broadcasting of information, via obstetricians, maternity hospitals, or booklets, was implemented by the health authorities.[12] This absence of national informative campaigns suggests that in France very few childbearing women are informed about the potential risk of methylmercury exposure. We therefore proceeded by employing a lab experiment rather than by observing purchase data in a real market setting.

4.1 Presentation of the lab experiment

We conducted the experiment in Dijon, the main city of Burgundy in France, in multiple sessions from January 23, 2006, to January 27, 2006. A sample of 120 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. As pregnancy and breastfeeding status or being a young child are crucial indications for risks linked to methylmercury, we focus on women of childbearing age, namely, women between 18 and 45 years of age. Table 2 shows that the distributions over age and female activity of this sample are relatively close to those of the French female population. Potential participants were contacted by telephone and had to agree to taste both sardines and tuna;

[12] One year after the study 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 (see, for instance, LCI, 2006). 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 planned in France.

otherwise, they were not selected. 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.

The lab experiment led to necessary restrictions in the number of products considered. As table 1 shows, six types of fish comprise 65% of the overall fish consumption in France. As salmon, cod, and hake are mainly sold fresh or frozen, they would have been very hard to handle during a one-hour experiment. This led us to a selection among three canned fish that are relatively handy in a lab and are also representative of French consumption habits (see the last column of table 1).

The choice between tuna and 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.[13] In other words, we tried to assure the similarity of a maximum number of elements (sauce, can color, weight, etc.) for avoiding additional biases. The other reason for the selection of tuna and sardines is the considerable difference in contents of mercury and omega-3, as shown in table 1. Tuna contains high mercury and low omega-3 levels, whereas sardines contain high omega-3 (in fact, the highest among fish) and low mercury levels (Sidhu, 2003, table 5, p. 341).

[13] Details can be found at 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. The similarity in weight and price allows a direct comparison of the products by the consumers in the experiment.

The contrasting contents in terms of mercury and omega-3s have important consequences for information revealed during the experiment. A description of the message used in the experiment is presented in appendix A. We restricted our attention to one benefit, namely, omega-3 fatty acids, and one risk, namely, methylmercury. The message was inspired by elements coming from health agencies in different countries as described in the previous section.[14]

The timing of the experiment is also presented in appendix A. This mechanism focuses on a single endowment point, which means we only use one type of product (fish I) for the initial endowment to exchange for different quantities of the other product (fish II), which facilitates revelation of information to subjects. 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 6 cans of tuna (endowment tuna) or 6 cans of sardines (endowment sardines). Fifty-eight participants (groups A and B) were endowed with 6 cans of tuna and 57 participants (groups C and D) were endowed with 6 cans of sardines. We started with a relatively large number of cans (6), since fish cans have a high shelf life (up to 5 years). At stages (5*ii*) and (5*iii*) defined in appendix A, the sequences of information revelation also differ, since groups A and C received details about omega-3s before details about mercury, and groups B and D received details about mercury before omega-3s.

For each choice procedure, namely at stage 5(i) before the revelation of information and at stage (5*ii*) and (5*iii*) after the revelation of information (see appendix A), participants had to indicate their selection in 12 choice situations. The 12 choice situations were presented on a single sheet of paper. The number of cans of fish II varied from 1 to 12, each corresponding to

[14] We detailed ratios quantifying the relative content of nutrients and contaminants based on table 1, which is unusual compared to current public health advisories. This choice provides scientific credibility in our context and

one situation. For each line, participants had to choose between 6 cans of fish I and q_{II} cans of fish II with $q_{II} \in \{1, , 12\}$ (see the choice sheet in Appendix A). The rest of the paper is based on a sample of 115 women who completed all choices at stages (5*i*), (5*ii*), and (5*iii*).

4.2 Results

The idea developed by Binswanger (1980) and Masters and Sanogo (2002) is to use respondents' choices to infer their relative preference and WTP. 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 this experiment, the consumer owns a given quantity of $\bar{q}_I = 6$ cans of fish I.[15] The experiment provides the selected quantities of fish II, q_{II}. The consumer is indifferent between the two product bundles when

$$\bar{q}_I \sim q_{II}. \tag{9}$$

Based on the 12 observed choices at stage *j* with $j \in \{i, ii, iii\}$ for steps (5*i*), (5*ii*), and (5*iii*) in appendix A, the experiment allows us to isolate the quantity $\tilde{q}^j_{II}$ for which $\tilde{q}^j_{II} - 1 \prec \bar{q}^j_I$ and $\tilde{q}^j_{II} \succ \bar{q}^j_I$.[16] This framework can be adapted to reveal relative WTP. As price $\overline{p}_I$ for fish I was posted (see point 3 in appendix A), the unknown WTP p_{II} for fish II can be determined. It

fits the restricted choice between only two types of fish in the experiment.

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

follows from previous inequalities that $p_{II}\left(\tilde{q}_{II}^{j}-1\right)<\overline{p}_{I}\overline{q}_{I}^{j}$ and $p_{II}\tilde{q}_{II}^{j}\geq\overline{p}_{I}\overline{q}_{I}^{j}$. Rewriting the previous inequalities with $\overline{q}_{I}=6$ leads to the following inequalities:

$$\frac{6}{\tilde{q}_{II}^{j}}\leq\frac{p_{II}^{j}}{\overline{p}_{I}}<\frac{6}{\tilde{q}_{II}^{j}-1}. \tag{10}$$

Equation (10) implies that the WTP for fish II, $p_{II}{}^{j}$, is approximated by

$$WTP_{II}^{j}=\frac{\overline{p}_{I}6}{\tilde{q}_{II}^{j}}. \tag{11}$$

Based on equation (11), we now turn to the WTP estimations coming from the experiment. Figure 1 presents the average values of the WTP for sardines (figures at the top for group A and B) and tuna (figures at the bottom for group C and D) before and after the revelation of information. These average values are based on all participants, including those not changing their choices after the revelation of information. Clearly, health information has a significant impact on the WTP, since participants substitute sardines for tuna. The WTP for tuna decreases because of relatively negative health information, while the WTP for sardines increases because of positive health information.[17]

From figure 1 it is easy to see that the order of information is determinant. It turns out that the information about mercury leads to a significant change in WTP whatever the order. In particular, if messages on methylmercury precede messages on omega-3s (for groups B and D),

[16] If during the experiment every $q_{II}\in\{1,\ldots,12\}$ 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 experiment no $\tilde{q}_{II}^{j}\in\{1,\ldots,12\}$ is observed for a respondent, we arbitrarily determined a value $\tilde{q}_{II}^{j}=13$.

[17] These results may differ from those that would be obtained in real markets, because of the focus on fish and health topics during the experiment. The information is revealed in the lab, a "protected" situation, and differs from regular purchase environments, where consumers face numerous sources of information (that are sometimes ambiguous) about a very large number of products. This focus in the experiment leads to a very accurate estimation of the cost of ignorance.

the major shift in WTP comes from the information on methylmercury. In other words, the information on omega-3s no longer causes a subsequent change in substitution. Information on omega-3s changed WTP significantly only if it came before information about mercury (for groups A and C).

One way to use results from figure 1 for determining regulatory scenarios consists in combining WTP coming from the experiment with the calibrated partial equilibrium model measuring imperfect substitution between sardines and tuna (see section 3) and being able to replicate prices and quantities in the French market.

5. Calibration for Computing Tax, Subsidy, and/or Information Policy

The calibration allows us to evaluate the market price modification and shifts in agents' surplus that would arise in response to taxes, subsidies, or information revelation based on the model presented in section 3 and the results coming from the lab experiment presented in section 4.

5.1 Methodology and data

From equation (3) in section 3, aggregated market demands for tuna and sardines are given by $X_t = \sum_{k=1}^{K} \overline{x_{tk}}(I, p_t, p_s)$ and $X_s = \sum_{k=1}^{K} \overline{x_{sk}}(I, p_t, p_s)$. Inverting these aggregated demands leads to the inverse demand functions

$$\begin{cases} p_t(I) = \alpha_t - \dfrac{\beta_t}{K} X_t - \dfrac{\gamma}{K} X_s - I.\dfrac{\sum_{k=1}^{K} r_{tk}}{K} \\ p(I) = \alpha_s - \dfrac{\beta_s}{K} X_s - \dfrac{\gamma}{K} X_t + I.\dfrac{\sum_{k=1}^{K} h_{sk}}{K} \end{cases} . \qquad (12)$$

By using (12), the differences between aggregate inverse demands with information for all consumers (corresponding to a perfect information case) and no information are given by $p_t(1) - p_t(0) = -\sum_{k=1}^{K} r_{tk} / K$ for tuna and by $p_s(I) - p_s(I) = \sum_{k=1}^{K} h_{sk} / K$ for sardines. These measures will be approximated by the values from the lab experiment where all participants received information. For instance, for tuna, the relative difference, $(p_t(1) - p_t(0)) / p_t(0)$, allows us to define a relative measure of the risk perception compared to the initial price $p_t(0)$. This value $(p_t(1) - p_t(0)) / p_t(0)$ may be approximated by the expected value of the relative variation of the expected WTP coming from the lab experiment. By using (11), a relative measure of the impact of information on preferences for product II (sardines or tuna) is given by

$$\delta_{II} = \frac{E(WTP_{II}{}^{\inf}) - E(WTP_{II}{}^{i})}{E(WTP_{II}{}^{i})} = \frac{E(\tilde{q}_{II}^{i})}{E(\tilde{q}_{II}^{\inf})} - 1 \quad (13)$$

where *E(.)* denotes the expected value over the subjects of the experiments (see figure 1 for these values), superscript *i* denotes the stage (5*i*) without information, and superscript *inf* denotes the stages (5*ii*) or (5*iii*) with information. Thus, δ_{II} represents the relative change in the per-unit WTP for fish II coming from health information compared to a situation at stage *i*, where no information was revealed. This measure does not depend on the initial endowment with product I.

By using (12) and (13), the average value of per-unit risks and per-unit benefits for the subgroup *z* are

$$\begin{cases} \bar{r}_t^z = \sum_{k=1}^{K_Z} r_{tk} / K_Z = -\hat{p}_t \delta_T^z \\ \bar{h}_s^z = \sum_{k=1}^{K_Z} h_{sk} / K_Z = \hat{p}_s \delta_S^z \end{cases}, \quad (14)$$

where K_Z is the number of people in a subgroup. The values δ_T^z and δ_S^z defined in (13) are given by the experiment. The values $\hat{p}_t = €6.1$ and $\hat{p}_s = €8.2$ are the average market prices per kilogram in France for tuna and sardines for the year 2002, the most recent complete year when the analysis was undertaken (see table 3). These prices come from the SECODIP database (see OFIMER, 2003). The prices per kilogram of "Connétable" cans (respectively €20.62 and €19.42) used for the experiment are clearly larger than the average prices of tuna and sardines. This implies that high-quality products were used for this experiment (recall from section 4.1 that our choice of products for the experiment was very limited). However, the relative WTP changes defined by (13) do not depend on the price of the fish I used for the experiment. In other words, the values δ_T^z and δ_S^z measure the relative WTP shifts coming from the information, whatever the initial values of fish I and II in the experiment. The absence of any initial prices in (13) makes it possible to use these values in a model taking into account overall demands of tuna and sardines in 2002.

The cost of ignorance defined by E_k in section 3 can be estimated using equation (14). To estimate the impact of information on demand, we divided the populations (and the overall demands) according to their risk status and their consumption habits. The subgroup 1 of households concerned by the mercury/omega-3 information includes all households with women of childbearing age and/or with young kids under age 14. We assume that men of these households also value the absence of methylmercury risks even if they are not directly concerned by this risk. Roosen et al. (2007) show that around 75% of fish consumption occurs at home (with some very tiny differences among men, women, and children) so that consumption behavior is highly correlated among members of the same family. From INSEE (1999), these households represent 50.5% of French consumers, so we assume they represent 50.5% of the overall demands. For this group, the estimation is given by taking into account the relative difference between the third and first bars in figure 1 since the third bar integrates the overall information (with both mercury and omega-3s). The average over groups A and B leads to a value $\delta_S^1 = 0.81$ for sardines and the average over groups C and D leads to a value $\delta_T^1 = -0.26$. By using average prices for 2002 (see table 3) and equation (14), this leads to a per-unit risk valued at $\overline{r}_t^1 = 1.59$ and a per-unit benefit valued at $\overline{h}_s^1 = 6.69$.

We assume that the other households (subgroup 2) are only concerned by the information about omega-3s for the reduction in cardiovascular risks. From figure 1, we consider the average value given by groups A and C, where the information about omega-3 was first provided and with no interference from information on methylmercury. For this group the estimation is given by taking into account the relative difference between the second and first bars in figure 1 since the third bar only integrates the omega-3 information. The average over group A leads to a value $\delta_S^2 = 0.47$ for sardines and the average over group C leads to a value $\delta_T^2 = -0.21$. By using average prices for 2002 (see table 3) and equation (14), this leads to a per-unit risk estimated at $\overline{r}_t^2 = 1.31$ and a per-unit benefit estimated at $\overline{h}_s^2 = 3.32$. Those values are lower for subgroup 2 than for subgroup 1, since methylmercury does not concern this subgroup 2. The average values over both subgroups (with a weight equal to 50.5% for subgroup 1) leads to a per-unit risk estimated at $\overline{r}_t = 1.45$ and a per-unit benefit estimated at $\overline{h}_s = 5.31$.[18]

We briefly detail the calibration of the initial demand in a context of absence of information. Parameters of the overall demand $X_t = \sum_{k=1}^{K} \overline{x_{tk}}(0, p_t, p_s)$ and $X_s = \sum_{k=1}^{K} \overline{x_{tk}}(0, p_t, p_s)$ (see equation (3) in section 3) are calibrated such as to predict prices and quantities for canned tuna

[18] This per-unit benefit $\overline{h}_s = 5.31$ linked to omega-3 and estimated by the experiment is relatively high compared to an initial sardine price $\hat{p}_s =$ €8.2. However, such a high level is "consistent" with the findings of Murphy and Topel (2006) who show a very large benefit linked to a reduction in the chances of dying from heart disease.

and sardines in France (under the absence of information) for the year 2002 (see table 3), the most recent complete year when the analysis was undertaken (Ofimer, 2003). The demand equations are represented by linear approximations with the corresponding elasticity at the point of approximation. We assigned values to the parameters based on elasticities that we estimated and show that canned fish are complements. The econometric model was estimated with a linear approximated almost ideal demand system (LA/AIDS) (see table 3 and appendix B).[19]

The overall demands without health information (at stage *i*) are defined by $X_t = a_t - b_t p_t + gp_s$ for tuna and $X_s = a_s - b_s p_s + gp_t$ for sardines. With the notations of table 3, the calibration leads to the values $a_t = \hat{X}_t + b_t \hat{p}_t - g\hat{p}_s$, $b_t = -\hat{\varepsilon}_{tt}\hat{X}_t / \hat{p}_t$, $g = \hat{\varepsilon}_{st}\hat{X}_s / \hat{p}_t$, $a_s = \hat{X}_s + b_s \hat{p}_s - g\hat{p}_t$, and $b_s = -\hat{\varepsilon}_{ss}\hat{X}_s / \hat{p}_s$.[20] This leads to aggregated demands of the entire French population without information and without tax and subsidy equal to

$$\begin{cases} X_t = 109596399 - 6991550 p_t - 378407 p_s \\ X_s = 17995428 - 512579 p_s - 378407 p_t \end{cases}. \tag{15}$$

Based on these demand functions, we computed the programs defined by (6) and (8) in section 3. We simplify the notations of section 3 by assuming that the information policy is able to reach a proportion $\kappa = k_1 / K$ of all consumers at a cost *C*. This parameter captures the imperfectness of an information policy based on hospital or media diffusion, which differs from

[19] 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. For 2002, the initial samples contain 5,362 households. Exclusion of households that did not report socio-demographic data results in a sample of 3,024. For each product, the quantity consumed and the amount spent during a year is recorded. Prices for non-consuming households are not available. A simple approach is taken by replacing the missing prices through averages calculated on data for consuming households.

[20] As we follow the Spence's (1976) specification in section 3, the parameter *g* for the demand of sardines is the same as the one previously defined for tuna demand (see equation (3) for cross parameters in equations). Demands would be very close to the ones presented in equation (15) if *g* were defined from a calibration with the sardines

the lab context in which all participants received a clear message (see section 4). The proportion $\kappa = k_1 / K$ and the information cost *C* are exogenously given for allowing a simple comparative static.[21]

5.2 Results

Table 4 provides the economic impact of regulatory tools. Under the first fiscal program (see equation (6)), the budget linked to the fish regulation is not balanced (but is completed/diminished by a lump-sum transfer provided by the rest of the economy and taken into account in the welfare), while under the second fiscal program, the budget linked to the fish regulation is balanced (see equation (8)). For program 2, the calibrated model is essential for computing simulations since simple analytical solutions are not possible for this program.

For each program, table 4 details the optimal tax/subsidy t_t, s_s (a negative level for s_s corresponds to a tax) determined with Mathematica. The second and fourth lines of each program present respective variations in the price of canned tuna and sardines compared to their initial prices $\hat{p}_t$ and $\hat{p}_s$ before any intervention. The budget linked to the regulatory policy is given by $B(t_t, s_s, I.C)$. The welfare (defined by equations (6) and (8)) is given by *W*, including that under the absence of any intervention with $t_t, s_s, I = 0$ (last line of table 4). Eventually, we provide the threshold cost C^* for which the information combined with the tax/subsidy leads to the same welfare as the policy without information but with the tax/subsidy (namely, the welfare

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quantity with $g = \hat{\varepsilon}_{ts} \hat{X}_t / \hat{p}_s$. Moreover, considering demands $X_t = a_t - b_t p_t + g_t p_s$ and $X_s = a_s - b_s p_s + g_s p_t$ with $g_t = \hat{\varepsilon}_{ts} \hat{X}_t / \hat{p}_s$ and $g_s = \hat{\varepsilon}_{st} \hat{X}_s / \hat{p}_t$ would be also possible.

value given in the first column for the same fiscal program). For instance, for program 1, it would be $W(p_t + t_t^*, p_s - s_s^*, 0) + B(t_t^*, s_s^*, 0) = W(p_t + t_t^{**}, p_s - s_s^{**}, \kappa K) + B(t_t^{**}, s_s^{**}, C^*)$).

Clearly, table 4 shows that regulation (tax/subsidy program and or information) increases welfare since welfare in the absence of regulation (last line of table 4) is dominated by the values of welfare for programs 1 and 2. Moreover, for similar values of κ and *I* (namely, for the same column in table 4), both fiscal programs linked to regulation are relatively similar in terms of consequences on welfare. For each column, fiscal program 1 leads to a slightly higher welfare than does fiscal program 2, but program 1 leads to a fiscal deficit/surplus (see the fifth line in table 4). Under program 1, the spending coming from a relatively high subsidy on a relatively low level of consumed sardines does not correspond to revenue coming from the relatively low tax on a relatively large level of consumed tuna. Thus, balancing the budget under program 2 leads to a slight tax decrease and to a slight subsidy increase compared to program 1. Program 2 imposes a little more distortion than does program 1, leading to a slightly lower welfare under program 2. As welfares under programs 1 and 2 are very close for the same range of parameters, a regulation on a fish market may be implemented autonomously without relying on alternative sources of financing.

If the proportion of informed consumers is $\kappa < 0.9573$ for program 1 and $\kappa < 0.9527$ for program 2, respectively, the welfare with a tax/subsidy program without any information (see the first column of table 4 with *I*=0) is higher than the welfare with both a tax/subsidy program and information policy. In other words, for program 1, if $\kappa < 0.9573$ and $C \geq 0$, the inequality $W(p_t + t_t^*, p_s - s_s^*, 0) + B(t_t^*, s_s^*, 0) > W(p_t + t_t^{**}, p_s - s_s^{**}, \kappa K) + B(t_t^{**}, s_s^{**}, C)$ is satisfied, and for

[21] An alternative assumption would consist of defining an optimal level of advertising/promotion with a cost $C(\kappa)$ with $C'(\kappa), C''(\kappa) > 0$ (see table 1, p. 427, in Kinnucan and Myrlan 2001 for values of promotion elasticity for France).

program 2, $W(p_t + t_t^*, p_s - s_s^*, 0) > W(p_t + t_t^{**}, p_s - s_s^{**}, \kappa K)$ is satisfied if $\kappa < 0.9527$ and $C \geq 0$. In this case, information policy is useless since the regulator would also impose a relatively high tax/subsidy for internalizing health risks/benefits for the proportion $(1-\kappa)$ of uninformed consumers. This tax would be a burden for the proportion κ of consumers informed about risks/benefits. A tax/subsidy program *à la* Pigou without information is optimal, since this program would directly internalize health characteristics not taken into account by unaware consumers.

The information policy (*I=1*) is socially profitable if a large proportion of consumers can be informed and if the information cost *C* is not too large (see the threshold cost C^* in table 4). This is the case if $\kappa > 0.9573$ for program 1 and $\kappa > 0.9527$ for program 2. Table 4 presents simulations corresponding to this configuration in the second and third columns where the cost of information is *C*=100 000 and κ slightly changes to allow for a comparative static. The main justification for providing information is that this strategy makes many consumers aware of health information (see section 4) while limiting the tax burden for consumers. Thus, the tax and subsidy internalizing health risks/benefits for the proportion $(1-\kappa)$ of uninformed consumers are low. Note that a situation of perfect information without any cost ($\kappa = 1$ and *C*=0, not detailed in table 4) leads to the highest welfare since there is no price distortion and consumers make fully informed decisions. When the information is efficient, the tax/subsidy becomes relatively inefficient because there is a negative welfare impact on consumers already informed and those not at risk from mercury in comparison to those at risk.

The tax/subsidy values with information in the second and third columns are relatively low compared to values without information in the first column. In the second column of table 4 ($\kappa = 0.97$), the tax on tuna finances the subsidy and the information for fiscal program 2. In this case, the tax and the subsidy are very limited, since they only internalize health benefits/risks for uninformed consumers (namely, a proportion $1-\kappa = 0.03$ of consumers). The third column details the optimal choice under perfect information when all consumers receive information $(\kappa = 1)$. Under program 1, no price distortion is necessary since the cost of information C is financed by other taxes/programs (with a lump-sum tax) and all the health information is directly internalized by consumers. Under program 2, the information policy is combined with a tax on both tuna and sardines for financing the information when the budget has to be balanced (program 2). In this case, the tax on sardines (equivalent to a high-quality product) is equal to -0.003 and it is larger than the tax on tuna (equivalent to a low-quality product). As under Ramsey pricing, it is optimal to impose the higher tax on the product with the lower demand elasticity (Viscusi et al., 2005).

6. Conclusions

This paper improves our understanding of how instruments influence consumers' behavior. There are three main implications in terms of regulatory economics.

First, based on our calibrated model, a tax/subsidy program seems to dominate an information policy in the case of fish consumption with health objectives. The information policy combined with a tax on tuna and a subsidy on sardines is socially beneficial only if a large proportion of consumers can receive the health information. This means that a regulator should target many consumers if information is chosen as a regulatory option.

Second, different options were considered in terms of the fiscal budget linked to the regulatory tools. As programs 1 and programs 2 in table 4 give relatively similar results, we conclude that a regulation on a fish market may be autonomously implemented without relying on alternative sources of finance. In other words, a market regulation regarding a specific product implying risks and benefits may be independently enforced.

Third, we showed that experimental results may help by comparing various regulatory scenarios. The methodology of this paper may be used by administrations, parliaments, or regulatory agencies for forecasting the consequences of their regulatory decisions.

In defining the analytical framework, very restrictive assumptions were made for simplicity. Some extensions could be easily considered for refining our results. For instance, more fish (as the ones in table 1) could be added in the simulations by taking into account their content in omega-3s or methylmercury. The experimental procedures could be replicated with more women in the sample and including other fish for measuring the robustness of our estimated WTP changes detailed in section 4. It would also be possible to add other nutrients, such as iodine or phosphorus, or contaminants, such as dioxin and PCBs, for determining an exhaustive tax/subsidy mechanism linked to fish. One could also consider other environmental objectives, such as the resource depletion of certain fish species, in combination with the health considerations of this study.

Producers' profits could also be considered for extending welfare measures (table 4), even if, in the supply chain, the price transmission determining profits at each stage of the production process is very hard to obtain. In the model, we also abstracted from any regulatory cost for implementing taxes or subsidies. A complete cost-benefit analysis should take into account these parameters to determine the optimal regulation for promoting healthy food.

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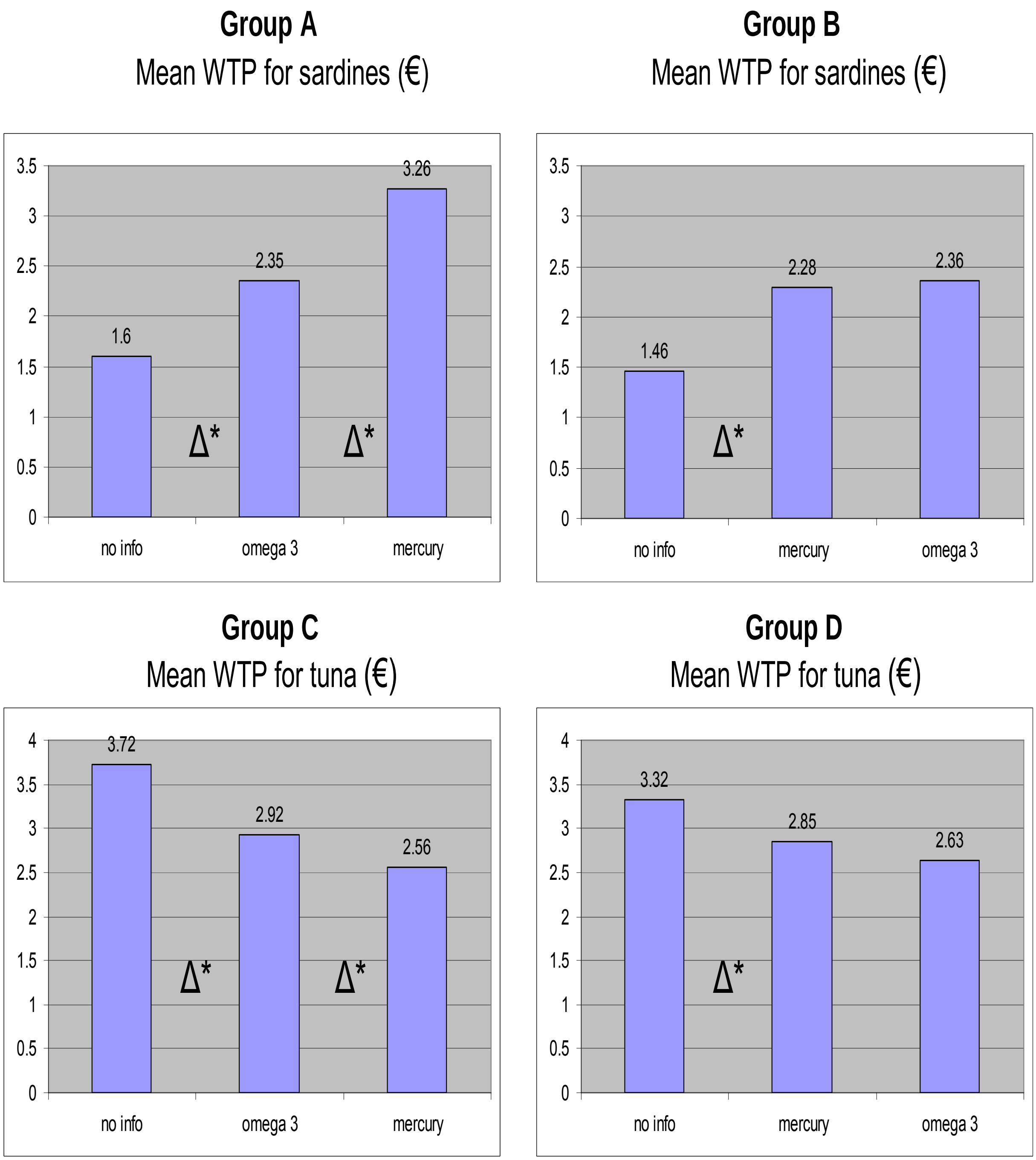
Figure 1. The effect of information in the lab experiment



Note: Δ* denotes significant difference at 5% as tested by the Wilcoxon test for comparing paired samples.

Table 1. Average content in omega-3s and in methylmercury for the top six fish purchased in France

	Omega-3s[*and**] g/100g	Methylmercury[***] mg/kg	Market share[a] in 2004 (volume)
Canned tuna	0.25[*]	0.27	27%
Salmon	2.35	0.02	10%
Hake (Alaska)	0.11	0.06	9%
Cod	0.09	0.10	7%
Canned sardines	3.3	0.05	6%
Canned mackerel	1.7	0.06	6%
Others			35%

Sources: * EFSA (2005, table 23 p.63); ** Sidhu (2003, table 5, p. 341); ***Table 1, p. 182, in Crépet et al. (2005).
[a] Percentage based on the sum of sold volume of fresh, frozen, and canned fish purchased by consumers in France in 2004 (OFIMER, 2005).

Table 2. Statistics about the sample in the experiment

	120 Women in the Experiment	Women in France[a]
Age		
Share by age group of women between ages 18 and 45		
18-24	22%	24%
25-34	44%	37%
35-45	34%	39%
Female working activity by age group[b]		
18-24	11%	29%
25-45	79%	81%

Notes: [a] Sources: For age in France:
http://www.insee.fr/fr/ffc/chifcle_fiche.asp?ref_id=NATCCF02120&tab_id=5
For activity by age group in France:
http://www.educnet.education.fr/insee/par/travail/txactivite.htm
[b] The definition of working women includes women searching for a job, but it excludes students.

Table 3. Demand specifications for households that purchase both canned tuna and canned sardines in France in 2002

Variable	**Description**	**Values**	
Tuna	Overall consumption $\hat{X}_t$ in France in 2002 (in kg)	63 845 000	
	Average price $\hat{p}_t$ per kg in 2002 (in euros)	6.1	
	Supply elasticity[a]	0.2	
Sardines	Overall consumption $\hat{X}_s$ in France in 2002 (in kg)	11 484 000	
	Average price $\hat{p}_s$ per kg in 2002 (in euros)	8.2	
Demand elasticities[1]		Tuna	Sardines
	Own-price	$\hat{\varepsilon}_{tt} = -0.668$	$\hat{\varepsilon}_{ss} = -0.366$
	Cross-price	$\hat{\varepsilon}_{ts} = -0.201$	$\hat{\varepsilon}_{st} = -0.382$

Sources: OFIMER, 2003; SECODIP, 2002.

[a]See appendix B for details about the econometric estimation.

Table 4. Economic effects of regulation (in euros)

	No Information $I=0$ C=0	***Information*** I=1, $\beta=0.97$ C=100 000	***Information*** I=1, $\beta=1$ C=100 000
Fiscal program 1			
t_t^*	1.45	0.043	0
$t_t^* / \hat{p}_t$ (%)	23%	0.7%	0%
s_s^*	5.31	0.159	0
$-s_s^* / \hat{p}_s$ (%)	–64%	–1.9%	0%
Budget $B(t_t^*, s_s^*, I.C)$	8 439 907	153 197	–100 000
Welfare W	336 862 806	336 906 108	337 361 443
Cost Threshold C*		143 303	498 638
Fiscal program 2			
t_t^{**}	1.38	0.042	0.001
$t_t^{**} / \hat{p}_t$ (%)	22%	0.68%	0.01%
s_s^{**}	5.64	0.164	–0.003
$-s_s^{**} / \hat{p}_s$ (%)	–0.68%	–2%	0.03%
Budget $B(t_t^{**}, s_s^{**}, I.C)$	0	0	0
Welfare W	336 811 708	336 906 091	337 261 436
Cost Threshold C**		194 398	549 511
No Policy			
($t_t, s_s, I=0$)			
Welfare W	325 166 035		

APPENDIX A: Timing and Message of the Lab Experiment

During the experimental session, women were asked to assess a choice between two types of fish. The 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 with an endowment of tuna (group A and B) and 57 participated in the treatment with an endowment of sardines (group C and D). The assignment of a convened group of consumers to either treatment was made at random. The session was divided into eight stages. The exact transcript of the experiment is available upon request from the authors.

(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 (see appendix A). 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

- (i) before receiving the health information;
- (ii) after receiving a message on omega-3 in groups A and C or message on mercury in groups B and D;
- (iii) after receiving a message on mercury in groups A and C or a message on omega-3 in groups B and D.

The choice sheet for those with a tuna endowment was the following (and the reverse for those with a sardine endowment):

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

After stage 5(i), the messages for the lab experiment was the following

OMEGA-3. Fish is important for 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. [*If endowment with tuna.*]
Sardines contain six-fold more omega-3 fatty acids than tuna. [*If endowment with 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.

MERCURY. Fish contains methylmercury (organic form of mercury) naturally present in water and coming from industrial pollutions. 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. [*If endowment with tuna.*]
Sardines contain four-fold less methylmercury than tuna. [*If endowment with sardines.*]
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 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.

(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 about their choices.

(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 risks linked to methylmercury.

APPENDIX B: Estimation of Demand Elasticities

The demand system used for the estimation is the almost ideal demand system (AIDS) (Deaton and Muellbauer, 1980). We consider a two-stage budgeting approach. After deciding on the optimal expenditures allocated to canned fish consumption, the household allocates shares to different types $i = 1, \ldots, n$ of fish in order to maximize utility subject to the milk budget. The expenditure share of household h on product i, w_{ih}, results in

$$w_{ih} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \log p_{jh} + \beta_i \log(x_h / P_h) \qquad i = 1, 2, \ldots, n \qquad \text{(A1)}$$

where p_{jh} are prices, x_h measures total canned fish expenditure, and P_h denotes the price index for household h. Consumer theory imposes the following constraints on the AIDS expenditure-share equations (1):

$$\sum_i \alpha_i = 1, \sum_i \beta_i = 0, \sum_i \gamma_{ij} = 0 \qquad \text{(adding-up)} \qquad \text{(A2)}$$

$$\sum_j \gamma_{ij} = 0 \qquad \text{(homogeneity)} \qquad \text{(A3)}$$

$$\gamma_{ij} = \gamma_{ji} \qquad \text{(symmetry)} \qquad \text{(A4)}$$

To incorporate socio-demographic variables into the demand system, we use a method of demographic translation. There are two ways to adjust for socio-demographic influences on household demand. Demographic translation preserves the linearity of the system and assumes that the constant terms in the share equation vary across households. Other methods (e.g., demographic scaling) have a nonlinear specification and allow relative prices and real expenditures to vary across households (Pollak and Wales, 1981, 1992). We use demographic translation and modify the constant in the share equations for goods $i = 1, \ldots, n$ into

$$\alpha_i = \rho_{i0} + \sum_{k=1}^{K} \rho_{ik} d_k \qquad \text{(A5)}$$

where ρ_{i0} and the ρ_{ik}'s are parameters to be estimated and $d_k, k = 1, \ldots, K$, are the socio-demographic variables. For adding up to hold requires that $\sum_{i=1}^{n} \rho_{i0} = 1$ and $\sum_{i=1}^{n} \rho_{ik} = 0$.

The full AIDS specification uses the translog price index defined as

$$ln(P_{ht}) = \delta + \sum_{m=1}^{N} \alpha_m \, ln(p_{mht}) + \sum_{m=1}^{N}\sum_{j=1}^{N} \gamma_{mj} \, ln(p_{mht}) ln(p_{jht}). \tag{A6}$$

Using (7) in (1) yields a nonlinear system of equations. A simplified approach is to estimate a linear approximated AIDS (LA/AIDS). Following Moschini (1995) and Buse and Chan (2000), we consider a linear approximation based on the Stone index defined as

$$log\, P_h^* = \sum_{j=1}^{n} \overline{w}_j \, log\, p_{jh} \, . \tag{A7}$$

Including the demographic translation, the finally estimated LA/AIDS for household *h* in period *t* results in a system of share equations to be estimated:

$$w_{ih} = \rho_{i0} + \sum_{k=1}^{K} \rho_{ik} d_{kh} + \sum_{j=1}^{n} \gamma_{ij} \, log\, p_{jh} + \beta_i \, log(x_h / P_h^*) + \varepsilon_{ih} \qquad \forall i \, . \tag{A8}$$

The elasticities are estimated at the sample mean following an approach suggested in Alston, Foster and Green (1994):

Expenditure Elasticity: $\eta_i = \dfrac{\hat{\beta}_i}{\overline{w}_i} + 1$ (A9)

Uncompensated own-price elasticity: $\varepsilon_{ii} = \dfrac{\gamma_{ii}}{\overline{w}_i} - \beta_i - 1$ (A10)

Uncompensated cross-price elasticity: $\varepsilon_{ij} = \dfrac{\gamma_{ij} - \beta_i \overline{w}_j}{\overline{w}_i}$ (A11)

Compensated own-price elasticity: $\varepsilon_{ii}^C = \varepsilon_{ii} + \overline{w}_i \eta_i$ (A12)

Compensated cross-price elasticity: $\varepsilon_{ij}^C = \varepsilon_{ij} + \overline{w}_j \eta_i$ (A13)

We use the French household panel SECODIP 2002 for the estimation. Excluding households that did not report socio-demographic data results in a sample of 3,024. As product groups, we consider canned tuna, canned sardines, and other canned fish (salmon, mackerel, and anchovies). Table B1 reports the sample statistics.

For each product the quantity (in kg) consumed and the amount in French francs (FF) spent during a year are recorded. Price is derived as unit value. Prices for non-consuming households are not available. While procedures exist to accommodate missing prices (e.g., Griffiths and Valenzuela, 1998; Erdem et al., 1999), they greatly complicate the implementation of the current estimation procedure. A simple approach is taken by replacing the missing prices with averages calculated on data for consuming households. The demographic variables include the number of household members (household size), monthly household income, and the socio-economic status of the household head.

The LA/AIDS has been estimated for the first two equations (table B2). Parameters of the third equation have been obtained from the restrictions A2 – A5. Standard errors of the restricted parameters and of the elasticities are estimated in a nonparametric bootstrap with N=500. Price elasticities that are not sensitive to the monetary unit, FF or euros, are provided in table B3. In table 3, we used the uncompensated elasticities for the simulations since the Spence model in (1) defines Marshallian surpluses.

Appendix B References

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TABLE B1. Sample statistics, SECODIP 2002

Variables	Mean	Std. Dev.
Quantities (kg/year)		
Canned tuna	2.451	2.901
Canned sardines	0.729	0.970
Other canned fish	1.122	1.663
Budget shares		
Canned tuna	0.568	0.342
Canned sardines	0.198	0.273
Other canned fish	0.234	0.289
Prices (FF)		
Canned tuna	42.442	33.622
Canned sardines	22.391	19.347
Other canned fish	22.158	17.105
Household composition and demographics		
Household size	2.899	1.402
Monthly household income (FF)[a]	13286.1	7862.3
Profession of household head (dummy variables)		
Farmer	0.023	
Handcrafter, retailer	0.024	
Management	0.065	
Intermediary professions	0.152	
Employees	0.129	
Worker (left out dummy in the estimation)	0.234	
Retired	0.319	
Other nonactive persons	0.030	

[a]Income categories have been transformed to a continuous variable using the midpoint of income intervals.

TABLE B2. LA/AIDS estimates

Variable	Canned tuna		Canned sardines		Canned other fish	
	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.[a]	Std.Err.
Constant	0.364***	0.016	0.292***	0.016	0.343***	0.019
Log price tuna	0.232***	0.006	-0.099***	0.04	-0.133***	0.007
Log price sardines	-0.099***	0.004	0.117***	0.006	-0.018***	0.004
Log price other fish	0.133***	0.005	-0.018***	0.005	0.151***	0.008
Log (X/P)	0.076***	0.004	-0.041***	0.004	-0.035***	0.007
Household size	0.007*	0.004	-0.014***	0.004	0.007*	0.004
Income	-0.000**	0.000	0.000***	0.000	0.000	0.000
Farmer	-0.082***	0.030	0.035	0.029	0.046	0.032
Handcrafter, retailer	-0.041	0.029	0.009	0.028	0.031	0.031
Management	0.010	0.021	0.001	0.020	-0.010	0.022
Intermediary professions	0.007	0.014	0.013	0.014	-0.020	0.014
Employees	0.015	0.015	-0.012	0.014	-0.003	0.015
Worker	-[b]		-[b]		-[b]	
Retired	-0.087***	0.013	0.085***	0.013	0.002	0.014
Other non active persons	0.041	0.027	0.078***	0.026	-0.037	0.029

***, ** and * indicate significance at the 0.01, 0.05 and 0.10 levels, respectively.
Canned Tuna: R^2 =0.469, Canned sardines: R^2 = 0.263.
[a]Calculated from constraints A2 - A5 . Standard errors obtained in a bootstrap of N=500.
[b] Left out dummy variable.

TABLE B3. Price and expenditure elasticities

Product groups	Price elasticities			Expenditure elasticities
	Canned tuna	Canned sardines	Other canned fish	
Uncompensated				
Canned tuna	-0.668***	-0.201***	-0.265***	1.134***
Canned sardines	-0.382***	-0.366***	-0.044*	0.791***
Other canned fish	-0.483***	-0.049**	-0.320***	0.851***
Compensated				
Canned tuna	-0.024**	0.024**	0.000	
Canned sardines	0.068**	-0.209***	0.142***	
Other canned fish	0.000	0.120***	-0.120***	

Asymptotic standard errors obtained in a bootstrap with N=500 are reported in parentheses.
***, ** and * indicate significance at the 0.01, 0.05 and 0.10 levels, respectively.