Tax, Minimum-Quality Standard, and Label for Regulating Environmental Quality:

A Welfare Analysis with Willingness to Pay Elicited in the Lab

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Abstract: The results of a lab experiment detailing consumers' valuations for the environment are used for estimating the welfare impact of a tax, a minimum-quality standard, and a label. Two approaches using consumers' valuations from the same experiment are considered for estimating welfare changes. The lab experiment is useful for identifying indifferent and concerned consumers, which is crucial for characterizing distortions determining the choice of instruments. Regarding the related empirical application, positive (negative) information revealed in the lab about the environmental effects linked to the shrimp production leads to a statistically-significant increase (decrease) in the willingness to pay. Based on these lab results, simulations show that the combination of a tax and a label is socially-optimal compared to other regulatory instruments.

Keywords: Regulatory instruments, environment, experimental economics, willingness-to-pay.

JEL codes: C91, H23, Q51.

1. Introduction

An increasing number of articles elicit consumers or citizens' willingness-to-pay (WTP) to making inferences about their preferences (Lusk and Shogren 2007). Many of these papers, however, do not actually derive welfare measures associated with regulatory instruments such as Pigouvian taxes, product minimum-quality standards, and/or labels. In other words, many survey or experimental papers that provide WTP estimates stop short of deriving welfare measures for policies serving as the impetus for the study.

More applied welfare studies on the regulatory instruments could help debates and complete the theoretical literature. Despite the abundance of theoretical works, no single instrument is clearly superior along all the objectives relevant to policy choices (Goulder and Parry 2008). Empirical analyses and case-by-case studies are therefore needed to highlight the overall effect linked to regulation. Instrument choice requires not only good estimates of WTP, but also reliable and quantified welfare estimation for measuring the impacts of different regulatory tools.

This paper focuses on the integration of WTP elicited in a lab experiment in partial equilibrium approaches for determining welfare impacts of environmental regulatory instruments. We show that the lab experiment is useful for identifying indifferent and concerned consumers regarding the characteristic of interest for the regulatory debate, namely in our case the environmental characteristic.

Two approaches using consumers' WTP from the same experiment are considered for estimating welfare changes. The first approach is based on a method directly using individual WTP elicited in the lab, while the second one draws on average WTP in conjunction with time-series demand estimates. Our purpose is to show that WTP estimates derived from survey/experimental methods may lead to a regulatory analysis detailing the impact of three main instruments, namely a per-unit tax on polluting products, a minimum-quality standard (MQS) impeding some levels of pollution, and a label signaling environmentally friendly products. We investigate the welfare impact of each instrument taken separately and the combined effects of a label with a per-unit tax and a label with a MQS.[1]

We use results of a lab experiment conducted in France in 2009 and focusing on the environmental effects associated with the shrimp production in developing countries. Results show that positive (negative) environmental information leads to a statistically-significant increase (decrease) in the consumers' WTP for shrimps. Based on these lab results, simulations show that the combination of a per-unit tax on polluting shrimps and a label signaling environmentally friendly shrimps is socially-optimal compared to the other instruments. Alternatively, if the label is unavailable, the MQS is socially-optimal compared to the tax. Welfare varies significantly across the two approaches used to measure it, but the regulatory choice is invariant.

Despite limitations coming from the experiment and the welfare estimations, the effects of instruments computed in this study are informative simulations that provide credible suggestions for the environmental policy. The chosen instruments are driven by consumers/citizens preferences and welfare maximization. This approach can appropriately complete analyses of environmental policy generally defined by ecological objectives aiming at capping pollution. Our paper follows the lead of Sunstein and Thaler who define the concept of "libertarian paternalism" attempting "to steer people's choices in welfare-promoting directions without eliminating freedom of choice" (Sunstein and Thaler 2003 p.1159). In other words, as citizens' knowledge is imperfect and unclear regarding pollution, a form of paternalism via a tax or a standard cannot be avoided a priori, while freedom of choices can be guaranteed by information/label.

This paper adds to the experimental literature by providing what we believe to be the first quantification of different regulatory options based on experimental WTP. Previous papers dealing with welfare/surplus mainly focus on the welfare impact of information revealed in the experiment and significantly impacting the WTP. The welfare impact of information is defined as value of information in contributions including Colson et al. (2008),

[1] In our simplified framework, products are either environmentally friendly or polluting, leading the MQS to impede the polluting products and to preclude the study of the combination of this standard with the per-unit tax.

Hu et al. (2005), Huffman et al. (2003 and 2007), Lusk et al. (2005), Lusk and Marette (2010), Marette et al. (2008a, 2008b and 2008c), Masters and Sanogo (2002), 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 may beef up the role of experimental data. Furthermore, we show that the ratio between consumers concerned about environment and indifferent consumers coming from the experiment is crucial for characterizing distortions determining the choice of regulatory instruments.

Our paper also contributes to the literature on environmental labeling by focusing on the combination of various instruments. We suggest that the role of information/label should be examined in relation with other regulatory instruments for questioning its efficiency. This differs from empirical papers focusing only on labels (Blend and Ravenswaay 1999; Teisl and Roe 2000; Teisl et al. 2002; Teisl 2003). Our results indicate that different instruments can be combined in the case of one market failure characterized by an under-investment in one environmental characteristic. This mitigates the classical idea that one market failure justifies employing one instrument (Goulder and Parry 2008).

The next section introduces the theoretical framework. We then present the two methods used for estimating welfare changes. Section 4 describes the experiment on shrimps and environment. Section 5 details the welfare estimation linked to the different instruments, while the last section concludes.

2. A simple theoretical model

Public intervention is useful to alleviate market failures that lead to sub-optimal choices by firms and consumers. Without any regulation, the emergence of environmentally friendly products is highly unlikely. The toolkit of instruments is however rather large. This section introduces a simple theoretical model to determine the welfare effects of three instruments taken separately (a per-unit tax, a MQS, and a label) and two of their combinations (a per-unit tax with a label, and a MQS with a label).[2] This model particularly matches issues linked to the lab experiment comparing choices between polluting and environmentally friendly shrimps and presented below.

For sake of simplicity, the presence or the absence of a label is exogenously given, which allows us to focus on consumers' choices. The label signaling a high-environmental quality is promoted and financed by the regulator under competition among producers, which allows the coexistence of polluting and environmentally friendly products without detailing the producers' strategies (implicitly, the competitive pressure leads to zero profits on the new segment promoted by the regulator).

Before investigating the welfare effects of the regulatory instruments, we briefly detail the demand and supply sides of the model. On the demand side, we consider two types of consumers: the concerned consumers with a utility impacted by the environmental characteristics of products and the indifferent consumers without any sensitivity to the environment. This division fits the experiment, where the concerned consumers react to the information revealed in the lab.

In this simplified framework, two products are available on the market: a regular product polluting the environment and an environmentally friendly labeled product.[3] The characterization of preferences largely follows Polinsky and Rogerson (1983). Demand of

[2] We only consider a voluntary label. We do not investigate the effects of a mandatory label, since it is redundant with the MQS, while consumers should be informed by an advertising campaign. The mandatory label with negative information about the polluting product is not considered, since it will be barred by lobbies. Therefore, "label" used hereafter will always refer to a voluntary label.

[3] The analysis can be applied to a situation for which the production pollutes the environment or a situation for which the consumption pollutes the environment. In our empirical application, the pollution is linked to the production. Consumers may benefit from some positive "warm-glow" by consuming products certified as respecting the environment or the global commons. Environmental and fair trade labels are well known examples of measures providing "warm-glow" to consumers with global-commons concerns regarding problems linked to unsustainable resource use in forest products, depletion of fish stocks or poor water management.

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:

$$U_i(q_{R\_i}, q_{L\_i}, w_i) = a(q_{R\_i} + q_{L\_i}) - \bar{b}(q^2_{R\_i} + q^2_{L\_i} + 2\theta q_{R\_i} q_{L\_i})/2 - Ir_i q_{R\_i} + Js_i q_{L\_i} + w_i, \quad (1)$$

where q_{R_i} is the consumption of polluting products and q_{L_i} is the consumption of environmentally friendly labeled products. The parameters $a, b > 0$ allow to capture the immediate satisfaction from consuming products and w_i is the numeraire good. The parameter θ measures the degree of substitutability between polluting and environmentally friendly products, with $\theta = 0$ for independent products and $\theta = 1$ for perfect substitutes.

The negative effect of pollution coming from the regular product is captured by the term $-Ir_i\, q_{R\_i}$ with the per-unit damage r_i ; the positive effect linked to the environmentally friendly product is captured by $Js_i q_{L\_i}$ with the per-unit benefit s_i. Information about the environmental characteristics of the products can be provided in the form of 'negative' or 'positive' messages, which suits our lab experiment. There may be important differences between the two types of messages since consumers may react differently to a negative signal compared to a positive one. The parameter *I* (respectively *J*) represents the consumers' knowledge regarding the environmental characteristic of the polluting product (respectively the labeled product). If consumers are not aware of the characteristic, then *I*=0 (or *J*=0). However, the characteristic is accounted for in the welfare via the non-internalized damage.[4] Conversely, *I*=1 (or *J*=1) means that consumers are aware of the characteristic r_i (or s_i) and internalize it in the consumption.

Concerned consumers see polluting and environmentally friendly products as different when both products are offered, which impacts their utility. The maximization of utility

[4] This non-internalized damage is slightly different from the cost of ignorance suggested by Foster and Just (1989). In Foster and Just's (1989) framework, consumers incur a cost of ignorance from consuming a contaminated product that could cause detrimental health effects without knowledge of the adverse information.

defined by (1) with respect to q_{R_i} and q_{L_i}, subject to the budget constraint with prices p_R for the polluting product and p_L for the environmentally friendly product gives inverse demands $p_R = Max\left[0, a - Ir_i - \bar{b}(q_{R\_i} + \theta q_{L\_i})\right]$ and $p_L = Max\left[0, a + Js_i - \bar{b}(q_{L\_i} + \theta q_{R\_i})\right]$. The respective-corresponding demands for a concerned consumer are:

$$\begin{cases} q^D_{R\_i}\ (p_R, p_L) = Max\left[0, \dfrac{a(1-\theta) - \theta Js_i - Ir_i - p_R + \theta p_L}{\bar{b}(1-\theta^2)}\right] \\ q^D_{L\_i}\ (p_L, p_R) = Max\left[0, \dfrac{a(1-\theta) + Js_i + \theta Ir_i - p_L + \theta p_R}{\bar{b}(1-\theta^2)}\right] \end{cases} \tag{2}$$

Indifferent consumers see both products as perfect substitutes with $\theta=1$ and $s_i = r_i = 0$. As the polluting product is less costly than the environmentally friendly labeled product, the indifferent consumers never purchase the labeled product. This leads to the following inverse demand function $p_R = Max[0, a - \bar{b}q_i]$ for the polluting product. The corresponding demand for the indifferent consumer *i* is $\bar{q}^D_{R\_i}(p_R) = Max\left[0, (a - p_R)/\bar{b}\right]$.

Individual demands are aggregated by subgroups making sense for the regulatory debate tackled by this paper. It is assume that a proportion *β=N₁/N* of consumers are concerned by the environmental characteristics of the polluting and environmentally friendly products, with $r_i = r$ and $s_i = s$ for every *i*=1,…, N_1. The proportion *(1-β)* = *1-N₁/N* of consumers is indifferent to these environmental characteristics with $s_i = r_i = 0$. For the concerned consumers, the aggregate demands are $Q^D_{R\_i}(p_R, p_L) = \sum_{i=1}^{N_1} q^D_{R\_i}(p_R, p_L) = N_1 q^D_{R\_i}(p_R, p_L)$ for the polluting product and $Q^D_{L\_i}(p_L, p_R) = \sum_{i=1}^{N_1} q^D_{L\_i}(p_L, p_R) = N_1 q^D_{L\_i}(p_L, p_R)$ for the environmentally friendly product. For the indifferent consumers, the aggregate demand for the polluting product is $\bar{Q}^D_{R\_i}(p_R) = \sum_{i=1}^{N-N_1} \bar{q}^D_{R\_i}(p_R) = (N - N_1)\bar{q}^D_{R\_i}(p_R)$.

When both polluting and environmentally friendly products are offered and with $b=\bar{b}/N$, $N_I=\beta N$ and $(N\text{-}N_I)=(1\text{-}\beta)N$, the overall inverse demands are:

$$\begin{cases} p_R^D(Q_R,Q_L,I)=Max\left[0,a-Ir-\dfrac{b(Q_R+\theta Q_L)}{\beta}\right] & \text{by concerned consumers} \\ p_L^D(Q_R,Q_L,J)=Max\left[0,a+Js-\dfrac{b(Q_L+\theta Q_R)}{\beta}\right] & \text{by concerned consumers} \\ \bar{p}_R^D(Q_R)=Max\left[0,a-\dfrac{bQ_R}{1-\beta}\right] & \text{by indifferent consumers} \end{cases} \quad (3)$$

When the environmentally friendly product is not offered, then $Q_L=0$ and $p_L^D(Q_R,0,J)=0$. In this case, the inverse demand of polluting product by concerned consumers is equal to $p_R^D(Q_R,0,I)$.

The supply side with a perfectly competitive industry and price-taking firms is defined by P_R for the polluting product and by P_L for the environmentally friendly labeled product. It is assumed that $P_R<P_L$, since the product respecting the environment is more costly to produce. We assume 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 do not detail profit functions that could explain the voluntary adoption of a label by producers (see Marette and Crespi 2003). The adoption depends on many parameters as the retailers' strategy and the contracts with farmers, the possibility to advertise, the existence of other labels, etc. This analytical simplification allows a sharper focus on the consumers' side in the welfare analysis.

We now turn to the analysis of the welfare effects of the policy instruments. To further simplify, it is assumed that regulation is costless. This leads us to study the 5 following regulatory scenarios and to compare them to the absence of regulation, namely (*i*) a per-unit tax on the polluting product, (*ii*) a MQS banning the polluting product, (*iii*) a label signaling the environmentally friendly product to consumers, (*iv*) a label signaling the environmentally friendly product with a per-unit tax on the polluting product, and (*v*) a label signaling the environmentally friendly product with a MQS banning the polluting product. Before detailing each scenario, we first present the market under the absence of regulation.

We focus on an initial situation where the negative damage r linked to the polluting product is not known by concerned consumers (I=0), which is compatible with our experiment where many participants are not aware of the environmental damage linked to the production of regular polluting shrimps. Figure 1 shows demands and supplies. The price is located on the vertical axis and the quantity is shown along the horizontal axis.

Under the absence of consumers' observation and regulation, the supply is represented by P_R. As the production of the polluting product is less costly, the environmentally friendly technology is driven out of the market with $Q_L = 0$. In the absence of a regulation signaling the difference between the polluting and the environmentally friendly technologies, no firm would be able to competitively supply the environmentally friendly product. The proportion β of concerned consumers is interested by the environmental characteristic of the polluting product even if they do not internalize it in their consumption (I=0). This subgroup has an overall demand D_1 representing $p_R^D(Q_R,0,0)$ defined by equation (3) with $Q_L = 0$. The proportion $(1-\beta)$ of consumers is completely indifferent to the environmental characteristic of the polluting product with a demand D_2 representing $\overline{p}_R^D(Q_R)$. 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 polluting product (equilibrium A). The non-internalized damage incurred by concerned consumers should be accounted for in the welfare calculation. This non-internalized damage is defined by rQ_1^A and represented by area $0(-r)wQ_1^A$, where Q_1^A is the consumption of the concerned consumers at price P_R. The consumers' surplus (area $P_R Aa$) minus the non-internalized damage yields an overall welfare represented by area $P_R Aa - 0(-r)wQ_1^A$.

Regulation is necessary for thwarting the absence of damage internalization by concerned consumers. We successively detail the impacts of 5 regulatory scenarios.

Insert figure 1 here

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

With a Pigouvian per-unit tax on pollution such that $P_R + t^* < P_L$, only the polluting product is available on the market. The tax increases the price of this product without eliminating the environmental damage. The tax t^* equal to βr maximizes the welfare defined by the sum of the consumers' surplus, the non-internalized damage and the tax income.[5] The equilibrium price of the polluting product is $P_R + \beta r$ with a market clearing equilibrium quantity Q^B (equilibrium B in figure 1). For the proportion β of concerned consumers, the non-internalized damage is defined by rQ_1^B and represented by area $0(-r)uQ_1^B$, where Q_1^B is the consumption of concerned consumers at price $P_R + \beta r$. The tax income for the regulator is $\beta r Q^B$ represented by area $0(\beta r) f Q^B$. Adding the consumer surplus (area $(P_R + \beta r)Ba$) to the tax income and subtracting the non-internalized damage yields an overall welfare represented by area $(P_R + \beta r)Ba - 0(-r)uQ_1^B + 0(\beta r) f Q^B$.

2.2. Scenario #2: The MQS banning the polluting product

Imposing a MQS, namely an environmentally friendly product at a price P_L, eliminates the product with the polluting characteristic. As no information is revealed to consumers, the demand does not change (with *I*=*J*=0), but the non-internalized damage incurred by

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

concerned consumers disappears. The price P_L with unchanged demand leads to the equilibrium *C* and a welfare $P_L Ca$.

Figure 1 depicts the changes in welfare when shifting from no regulation to a MQS. Two opposite effects can be identified. First, the MQS fully eliminates the non-internalized damage represented by area $0(-r)wQ_1^A$ under equilibrium *A*. Second, the MQS induces an increase in production costs, a supply shift and a price increase from P_R to P_L. The effect of the MQS i.e., the comparison between the welfare $P_R Aa - 0(-r)wQ_1^A$ with no regulation and the welfare $P_L Ca$ under the MQS is ambiguous and depends on the per-unit damage, *r*, and the proportion β of concerned consumers. If area $0(-r)wQ_1^A$ is lower than area $P_R ACP_L$, the increase in price is too large and the MQS is not socially beneficial. Alternatively, if area $0(-r)wQ_1^A$ is larger than area $P_R ACP_L$, the MQS is socially beneficial.

2.3. Scenario #3: The label signaling the environmentally friendly product

Labels are more favorable to product diversity: they allow the presence of various products bought by consumers in full knowledge of the facts. In the presence of labels, the market is segmented and environmentally friendly products coexist with polluting products.

For simplicity, it is assumed that the label fully transmits the relevant information, is fully understood by all consumers (i.e. *J*=1, see equations (1) and (3)) and allows them to identify the positive environmental characteristic of the labeled product.[6] It is also assumed that *I*=0, which means that consumers are ignorant about the negative environmental characteristic of the polluting product.[7] In other words, they see the labeled product as an

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[6] One of the main limits of a labeling policy lies in the low memorization capacity of consumers and the possible confusion as soon as the delivered information is technical or complex (Wansink et al. 2004).

[7] The alternative case with *I*=1 could be considered, particularly for crisis situation where the polluting product suffers from a bad collective reputation.

environmentally friendly product and they misperceive the damage entailed by the polluting product. This is common to situations where information conveyed by labels is positive.

Figure 2 presents the market situation with a label. The demands coming from equation (3) are represented with bold curves. To ease the comparison, the initial situation *A* without regulatory intervention presented in figure 1 is also represented in figure 2. After the label's introduction, some concerned consumers continue to purchase the polluting product (without knowing the damage linked to it) because of its lowest price. The group of concerned consumers with an initial demand D_1 (under the absence of regulation) is therefore divided between consumers choosing the polluting product with $\overline{D}_{1\_R}$ representing $p_R^D(Q_R, \overline{Q}_L, 0)$ defined by (3), and consumers choosing the environmentally friendly product with $\overline{D}_{1\_L}$ representing $p_L^D(\overline{Q}_{R\_1}, Q_L, 1)$. The overall demand for the polluting product equals $\overline{D}_{1\_R} + D_2$, when indifferent consumers are taken into account (D_2 alone is not represented).

Therefore, two prices P_R (for the polluting product) and P_L (for the environmentally friendly product) clear the market. At the equilibrium, concerned consumers purchase a quantity $\overline{Q}_{R\_1}$ of the polluting product and a quantity $\overline{Q}_L$ of the environmentally friendly product. For concerned consumers purchasing the polluting product, the non-internalized damage is defined by $r\overline{Q}_{R\_1}$ and represented by area $0(-r)x\overline{Q}_{R\_1}$. The welfare is defined by the area $P_L L(a+s) + P_R Ra - 0(-r)x\overline{Q}_{R\_1}$.

Insert figure 2 here

2.4. Scenario #4: The label signaling the environmentally friendly product with the per-unit tax on the polluting product

As previously mentioned, some concerned consumers continue to choose the polluting product after the label's introduction because of the relatively high price P_L. A per-unit tax

t^{**} could be combined with the label to reduce the non-internalized damage incurred by these consumers. The market situation is depicted on figure 3. Compared to scenario #1, polluting and environmentally friendly products are now available on the market and the tax modifies the demands $\overline{D}_{1\_R}$ and $\overline{D}_{1\_L}$ represented by dashed curves on figure 3, since both products are imperfect substitutes (see equation (3)). The new curves are represented by bold curves $\tilde{D}_{1\_R}$ and $\tilde{D}_{1\_L}$. At the equilibrium, concerned consumers purchase a quantity $\overline{Q}_{R\_1}^{tax}$ of the polluting product (equilibrium *T*) and the equilibrium is *L'* for environmentally friendly product. For concerned consumers purchasing the polluting product, the non-internalized damage is defined by $r\overline{Q}_{R\_1}^{tax}$ and represented by area $0(-r)z\overline{Q}_{R\_1}^{tax}$. The welfare is defined by the area $P_L L'(a+s)+(P_R+t^{**})Ua-0(-r)z\overline{Q}_{R\_1}^{tax}$.

Insert figure 3 here

2.5. Scenario #5: The label signaling the environmentally friendly product with the MQS banning the polluting product

In this last scenario, only the environmentally friendly product is available on the market. As shown by figure 4, the label leads to a demand increase (via the parameter *s*) and the MQS banning the polluting product gets rid of the non-internalized damage.

The demands coming from equation (3) are represented with bold curves (dashed curves represent cases presented in figures 1 and 2). Concerned consumers purchase environmentally friendly products with a demand $\hat{D}_{1\_L}$ representing $p_L^D(0,Q_L,1)$. The demand increases from $\overline{D}_{1\_L}$ to $\hat{D}_{1\_L}$ because of the absence of polluting product coming from the MQS. The overall demand for the new product signaled with the label equals $\hat{D}_{1\_L}+D_2$, when indifferent consumers who do not change their demand are taken into account (D_2 alone is not represented). The equilibrium is defined by *S*. The welfare is defined by the area $P_L S\alpha(a+s)$.

The selected regulatory instrument will be the one maximizing the welfare. However, there is no clear theoretical conclusion about the optimal instrument to select. The label improves welfare compared to other tools since diversity and freedom of choice are beneficial for the society. On the other hand, prohibitive labeling costs, imperfect advertising and/or a high risk of muddle among consumers regarding the significance of the label may lead to the selection of a MQS as the socially optimal choice. The policy-maker may also combine different instruments. For example, as the non-internalized damage is equal to $0(-r)x\overline{Q}_{R\_1}$ with the label, the regulator may combine the label with a per-unit tax imposed on the polluting product leading to an increase in the price of this product. Hence, empirical welfare estimates using calibrated equilibrium models and results from experiments or surveys are precious to inform regulator's choices between taxes, MQS and labels. The empirical evaluation of the trade-offs involved is a crucial step for rigorous and convincing cost-benefit analyses.

Insert figure 4 here

3. Two approaches for estimating surplus changes

In this section, we briefly compare two approaches for estimating the welfare effects described in figures 1-4. The first approach is based on individual estimates of WTP, while the second one uses average WTP with time-series demand.

3.1. Approach #1: Individual WTP

Approach #1 directly uses individual estimates of WTP. The proportion of concerned and indifferent consumers directly matters via the WTP variations, but we do not distinguish between both groups for simplifying the presentation.

We assume that a consumer purchases a good if his WTP is higher than the price of the good. Under the absence of regulation, only the polluting product is available on the market. Consumer i can therefore choose between two outcomes: polluting product at price P_R and none. She/He chooses the option generating the highest utility (with a utility of non-purchase normalized to zero):

$$CS_1^i = \max\{WTP_1^i - P_R, 0\}, \tag{4}$$

where the subscript 1 denotes the WTP linked to choice #1 (before information revelation) for a consumer i (with $i = 1, \ldots, N$).

Our experiment has equally divided participants in one group receiving positive environmental information and one group receiving negative environmental information. The group receiving the negative information is useful for computing the non-internalized damage linked to the lack of precise information about the environmental characteristic of the polluting product (as before choice #1). When negative and precise information is revealed (before choice #2), some consumers stop buying the polluting product. For a consumer i, a measure of the non-internalized damage before choice #1 is $Z_i[WTP_2^i - WTP_1^i]$, where the subscript 2 denotes the WTP linked to choice #2 (after information revelation) and Z_i is an indicator variable taking the value of 1 if consumer i is predicted to have chosen the polluting product at price P_R with $WTP_1^i > P_R$ in choice #1 (and zero otherwise). Note that the measure $Z_i[WTP_2^i - WTP_1^i]$ is negative since $WTP_2^i < WTP_1^i$ with the group receiving the negative information. The average per-unit value of the non-internalized damage linked to the polluting product is:

$$E(D) = \frac{\sum_{i=1}^{N_N} Z_i[WTP_2^i - WTP_1^i]}{\sum_{i=1}^{N_N} Z_i}, \tag{5}$$

where N_N is the overall number of consumers in the group receiving negative information and $\sum_{i=1}^{N_N} Z_i$ is the number of consumers who purchase the polluting product based on WTP revealed by choice #1.

The measure $E(D)$ coming from the group with negative information is integrated to the consumer *i*'s direct surplus CS_1^i with *i* belonging to the group with positive information, which determines the overall welfare. In other words, consumers take their decision based on the surplus defined by (4), but the welfare measure integrates an estimation of the non-internalized damage.

In the absence of regulation, the overall per-unit welfare is therefore:

$$CSD_{No\,\mathrm{Re}\,gulation}^{N_P} = \frac{\sum_{i=1}^{N_P}[CS_1^i + Z_i E(D)]}{N_P} = \frac{\sum_{i=1}^{N_P}\left[\max\left\{WTP_1^i - P_R, 0\right\} + Z_i E(D)\right]}{N_P}, \tag{6}$$

where N_P is the overall number of consumers in the group receiving positive information.

For measuring the welfare under the per-unit tax and MQS scenarios, we use the WTP before the revelation of information (i.e. before choice #1). In both scenarios, only one good (polluting under the tax scenario and environmentally friendly under the MQS scenario) is available on the market. Therefore, consumers can only choose between two options: the product available on the market and none.

The per-unit tax *t* changes the purchasing decision, with an overall per-unit welfare:

$$CSD_{Tax}^{N_P} = \frac{\sum_{i=1}^{N_P}[CS_1^i + Z_i' E(D) + tZ_i']}{N_P} = \frac{\sum_{i=1}^{N_P}\left[\max\left\{WTP_1^i - P_R - t, 0\right\} + Z_i' E(D) + tZ_i'\right]}{N_P} \tag{7}$$

where Z_i' is an indicator variable taking the value of 1 if consumer *i* is predicted to have chosen the polluting product at price P_R+t if $WTP_1^i > P_R + t$ in choice #1 (and zero otherwise). This tax negatively influences Z_i'.

The MQS imposes a more expensive product at price $P_L > P_R$. The non-internalized damage vanishes since the polluting product disappears. As consumers are not aware of the standard, only WTP_1^i (before the revelation of information) is taken into account in the surplus. The overall per-unit welfare is:

$$CSD_{Std}^{N_P} = \frac{\sum_{i=1}^{N_P}\left[\max\left\{WTP_1^i - P_L, 0\right\}\right]}{N_P}. \tag{8}$$

We now turn to the case with label and use the WTP before and after the revelation of information. When a label is introduced at price P_L (before choice #2), consumer i can choose between three options (polluting product, environmentally friendly product and none). We assume that consumer i is still ignorant about the negative characteristic of the polluting product (I=0) and only aware of the positive information coming from the label for choosing between the three options. The consumer takes its decision based on her/his surplus $CSD_2^i = \max\left\{WTP_1^i - P_R, WTP_2^i - P_L, 0\right\}$. The non-internalized damage linked to the polluting product is taken into account with $E(D)$ in the welfare and $\tilde{Z}_i$ is an indicator variable taking the value of 1 if consumer i is predicted to have chosen the polluting product at price P_R when the label exists on the market (and zero otherwise). In this case, the overall per-unit surplus is:

$$CSD_{Label}^{N_P} = \frac{\sum_{i=1}^{N_P}\left[CSD_2^i + \tilde{Z}_i E(D)\right]}{N_P} = \frac{\sum_{i=1}^{N_P}\left[\max\left\{WTP_1^i - P_R, WTP_2^i - P_L, 0\right\} + \tilde{Z}_i E(D)\right]}{N_P}. \tag{9}$$

The two other cases, namely the label combined with the tax or the MQS are not described because of lack of space but they can easily be determined by combining (7) and (9) or (8) and (9).

Variations of per-unit welfare can be computed by comparing the welfare defined by (7), (8) or (9) to the one defined by (6) under the baseline scenario (without regulation). Eventually, this variation of per-unit welfare will be completed by an aggregate welfare variation consisting in multiplying this per-unit measure by the number of times the product is consumed over a period in a country. The variation of the per-unit welfare linked to scenarios takes into account the variation of market shares $\left(\sum_{i=1}^{N_P} Z_i' - \sum_{i=1}^{N_P} Z_i\right)/N_P$ or $\left(\sum_{i=1}^{N_P} \tilde{Z}_i - \sum_{i=1}^{N_P} Z_i\right)/N_P$ allowing an estimation of the equilibrium quantity (with notations defined with equations (6) to (9)).

3.2. Approach #2: Average WTP with time-series demand

This second approach relies on a combination of an elasticity of demand coming from time-series economics and the average WTP value obtained from an experiment. Time-series econometrics provides "well established" estimates of aggregate demand elasticity. Average WTP coming from the experimental auctions can be used to calculate the parameters *r* (per-unit damage) and *s* (per-unit benefit) defined in (1), which in turn are helpful to determine the welfare effects of information or public policy. The welfare variations under approach #2 are directly given by analytical expressions corresponding to areas described by figures 1-4. We simply provided essential details linked to the calibration.

With approach #2, the parameters *a* and *b* in (2) can be determined by classical calibration methods. For the baseline scenario without regulation, only the polluting product is offered at price P_R. The inverse demand for the polluting product is given by $P_R(Q_R) = a - bQ_R$. 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 $\tilde{a} = \tilde{b}\hat{Q}_R + P_R$. Note that the parameter $\tilde{b}$ is inversely related to the elasticity, $\hat{\varepsilon}$.

The different regulatory scenarios can be computed by estimating *r, s* and θ (see equation (1)) with the experiment. First, the parameter *r* defining the non-internalized damage is linked to the polluting product. The parameter r is determined by WTP data coming from the group receiving the negative information with values WTP_1^i and WTP_2^i indicating concerned consumer *i*'s WTP before and after the revelation of information (as described for approach #1). The relative variation in WTP provides a measure of the inverse demand shift, $\delta = \left[E(WTP_2) - E(WTP_1)\right]/E(WTP_1)$, where E denotes the expected value over participants. This relative variation is extrapolated to measure the variation of overall demands defined by (3). The inverse demand curves can be viewed conceptually as maximum WTP curves, where the price can be replaced with WTP. Thus, using the inverse demands for the concerned consumers in equation (3), the relative price variation is equal to the inverse demand shift defined by $[p_R^D(Q_R,0,1) - p_R^D(Q_R,0,0)]/p_R^D(Q_R,0,0) = \delta$. From equation (3) the equality $p_R^D(Q_R,0,1) - p_R^D(Q_R,0,0) = r$ and from the equilibrium $p_R^D(Q_R,0,0) = P_R$, the estimated value is $\tilde{r} = -\delta P_R$. With $\delta < 0$, the value $\tilde{r} = -\delta P_R$ is positive but negatively impacts welfare linked to demands defined by (2) and (3).

The values s and θ taken into account in (3) depend on the imperfect substitution between polluting and environmentally friendly products. For the concerned consumers, the first two equations of (3) can be rewritten as $p_R^D(\overline{Q}_R,\overline{Q}_L)$ and $p_L^D(\overline{Q}_R,\overline{Q}_L)$, where $\overline{Q}_R,\overline{Q}_L$ are the quantities they bought. As *a* and *b* were previously determined in the initial calibration (i.e. in the baseline scenario without regulation), the parameter θ is determined by solving $p_R^D(\overline{Q}_R,\overline{Q}_L,0) = P_R$. From the estimation of θ, the second equation of $p_L^D(\overline{Q}_R,\overline{Q}_L,1) = P_L$ can be solved for finding s. From the experiment, it is possible to determine $\overline{Q}_R,\overline{Q}_L$. We know the percentage M of consumers choosing the polluting product under the absence of label. After the introduction of the labeled product and from participants receiving positive information during the experiment, we are able to determine the percentage M_1 of consumers choosing polluting product and the percentage M_2 of consumers choosing the environmentally friendly product. Compared to the initial observed quantity $\hat{Q}_R$ of the polluting product sold on the market before the introduction of the environmentally friendly product (used for determining $\tilde{a}$), the estimated equilibrium quantities $\overline{Q}_R, \overline{Q}_L$ are such that:

$$\begin{cases} \dfrac{M_1 + M_2}{M} = \dfrac{\overline{Q}_R + \overline{Q}_L}{\hat{Q}_R} \\ \dfrac{M_1}{M_2} = \dfrac{\overline{Q}_R}{\overline{Q}_L} \end{cases} \tag{10}$$

These two approaches show the importance of choices elicited in the lab. We now turn to the experiment used in this paper.

4. The experiment on shrimps

We conducted the lab experiment in Paris, France in December 2009. 79 participants, aged between 18 and 85 years, were randomly selected based on the quota method. They were contacted by phone and informed that the experiment would focus on food behavior and shrimp consumption and would last about one hour with a €15 indemnity. The sample is relatively representative of the age-groups and the socio-economic status of the population of the city although retired people are slightly over-represented. In our experiment, the sample is divided into two groups and participants are randomly assigned to one group. Group I (39 participants) receives positive information about the environmental characteristic of shrimps, while group II (40 participants) receives negative information. Fisher and Pearson chi-square tests show that the two groups are not significantly different in terms of socio-economic characteristics (gender, age, education, income, household composition).[8]

The experiment focuses on 100g plastic package of farmed, midsize, shelled, cooked and refrigerated shrimps.[9] The inclusion of an environmental friendly label on the picture of the package of environmentally friendly shrimps presented to participants was the only way for them to distinguish between polluting and environmentally friendly shrimps. The experiment elicits hypothetical responses, since we do not offer the product at the end of the

[8] Results are available from the authors.

[9] Cooked and refrigerated shrimps are the most consumed shrimps in France (FranceAgriMer 2009). Statistics do not distinguish between shelled and non-shelled shrimps.

experiment and this for two reasons. First, for really measuring the marginal value of the environmental characteristic with sequential choices, polluting and environmentally friendly products would have to be similar in a maximum number of elements, namely, brand, sauce, weight, packaging, and price. Such a similarity between both products did not exist on the French market at the time of the study. Second, the cold process linked to refrigeration makes indeed the sale/distribution of products to participants hazardous in terms of food safety. Despite possible hypothetical biases in the WTP elicitations, the protocol precisely controls the revelation of information in the lab.

Based on the previous literature, the risks of possible hypothetical biases can be downplayed regarding the welfare measures, since the marginal WTP (namely the difference between WTP_2 and WTP_1) is used under approaches #1 and #2. By comparing hypothetical and non-hypothetical responses, Lusk and Schroeder (2004) showed that marginal WTP for a change in quality/characteristic is, in general, not statistically different across hypothetical and real payment settings. Moreover, Camerer and Hogarth (1999) showed that performance-based financial incentives have little effect on mean responses.

The experiment is divided into several stages. Participants receive general instructions and sign a consent form. They fill in an entry questionnaire on consumption behavior and socio-demographic characteristics. Two successive types of information are then communicated. After each message, participants' WTP is elicited. In the first message, we provide general information about the shrimps. A range of existing prices observed in supermarkets (between €1.50 and €4) is mentioned. In the second message, we provide information about possible environmental production conditions linked to shrimps. Recall that group I receives positive information, while group II receives negative information (see the appendix for the complete messages). Participants fill in an exit questionnaire and receive the €15 indemnity.

A multiple price list presented on a paper sheet is used for eliciting participants' WTP. During each choice phase, participants are asked to choose whether or not they will buy the 100g plastic package of farmed, midsize, shelled, cooked and refrigerated shrimps for prices varying from €0.25 to €4 with a 25-cent interval between possible choices. A colored picture of the shrimp package (accompanied by a label for environmentally friendly shrimps) is posted on the paper sheet. As no major brand dominates the market, the private brand (linked to a French supermarket) is concealed to avoid any influence of this supermarket brand. For each price, participants have to check off either “yes”, “no” or “maybe” regarding their purchase intentions. The option “maybe” is useful for capturing hesitation that differs from a firm “yes”. For each choice #*i* with i={1,2}, the WTP is determined by taking the highest price linked to a “yes” choice. If no “yes” is checked off, we set the WTP to zero. If “yes” is always selected, we set the WTP to €4.

Andersen et al. (2006) underline two disadvantages of the multiple price list. The first disadvantage is the interval response eliciting interval from participants rather than point estimates for WTP. With our experiment, the 25-cent interval guarantees enough precision for the elicited WTP. The other disadvantage is the framing effect with a psychological bias towards the middle of the multiple price list for choices made by participants. We do not control for this framing effect. However, the psychological bias is not really plausible in our experiment: for the first round, only 12.7% of participants expressing a WTP of €2. And this percentage is even smaller after the second message. Only 6.3% of participants make a bid of €2 in choice #2.

Despite these limitations, the multiple price list methodology is useful for providing information regarding the consumers’ WTP. The main advantage is the simplicity of the explanation given to participants at the beginning of the experiment, which differs from auction mechanisms where organizers need to convince participants that bid manipulation is useless under a Vickrey mechanism.

Figure 5 shows the average WTP in euro expressed by consumers in both groups I and II after each message. We report the average WTP for all consumers, as well as for the two sub-groups of concerned and indifferent consumers. The standard deviation is reported in parentheses. A few consumers increased (respectively decreased) their WTP after the revelation of negative (respectively positive) environmental information. These unexpected variations may indicate a rejection of the environmental issues by consumers. However, the inclusion of these consumers in the group of concerned consumers may bias the results of this group. We therefore decided to treat them as indifferent consumers and set their WTP in choice #2 at the same level as in choice #1.[10] The share of concerned consumers over all consumers (defined in the previous section by β) is β_I=0.67 for group I and β_{II}=0.32 for group II.

Insert figure 5 here

Group I (respectively group II) receives positive environmental information before the second choice (respectively negative information). The indicator Δ isolates the significant impact of environmental information. We test for the significance of the WTP differences (namely, between WTP #1 and WTP #2) by using the Wilcoxon test for paired samples.

Three main results could be highlighted from figure 5. First, the initial WTP before the revelation of any information about the environment is similar across the two groups. A Kruskal-Wallis test concludes that the valuation for the first round across groups I and II is not statistically significant. Second, for concerned consumers, information about the environment leads to a significant change in WTP. This change is significant at the one percent level and holds whatever the type of information (positive or negative). Third, for concerned consumers, negative information has a larger impact in absolute value than positive information. For concerned consumers, the average variation in absolute value between the two WTP is equal to €2.32 for group II, and only to €0.87 for group I. The difference is mitigated when all consumers are taken into account, since the average variation

[10] In a real-life situation (i.e. in supermarket), these consumers are very likely to buy the polluting product even if they have the choice between polluting and environmentally friendly products. Our approach is therefore not too far from the reality.

in absolute value between the two WTP is equal to €0.87× β_I =0.58 for group I, and €2.32× β_{II} =0.74 for group II. These results are consistent with the previous literature showing that consumers tend to be more reactive to the negative information (Hayes et al. 1995).

The results from figure 5 are now used for conducting the welfare analysis of regulatory scenarios presented in the previous section.

5. Welfare analysis under various regulatory scenarios

Using the two approaches for computing the welfare changes and the results of the experiment described above, we evaluate the welfare variation and the shifts in agents' surplus that would arise in response to a per-unit tax, a MQS, a label, a label with a tax and a label with a MQS.

Data necessary for calibrating the welfare variation under approaches #1 and #2 are reported in table 1. These data are useful for replicating prices and quantities of shrimps sold in 2008 in the French market.

Insert table 1 here

Table 2 provides the economic impact of the different regulatory tools on the welfare by presenting welfare variations. For approach #1 (first column), we present the per-unit welfare variation (for 100g of shrimps) coming from equations (7), (8), (9) (subtracted from (6)). The aggregate welfare variation over the year is given by multiplying the per-unit welfare variation (for 100g) by $\hat{Q}_R$ the number of times 100g of shrimps are consumed over the year and defined in table 1.

For approach #2 (second and third columns), to improve the robustness of results, we consider two cases for the share β of concerned consumers: β_I=0.67 coming from group I and β_{II}=0.32 coming from group II. The case with β_I=0.67 is a priori close to approach #1, for which surpluses determined by equations (6) to (10) largely used group I receiving the positive information (group II leading to the determination of the non-internalized damage).[11] Welfare variations (calculated with the *Mathematica* software) are computed by taking into account the welfare under a given scenario minus the welfare under the baseline scenario, which is defined by the absence of regulation.

Five main conclusions could be derived from table 2.

(i) All welfare variations are positive, which means that the regulation increases the welfare.[12] The per-unit tax and the MQS with a higher cost negatively impacts the equilibrium quantity (see figure 1, $Q^B < Q^A$). However, the welfare increases since the reduction of the negative impact of the non-internalized damage outweighs the negative effect of the quantity reduction. The label positively impacts the equilibrium quantity and the welfare since a new segment is created. Eventually, the absence of quantity variation for the scenarios combining the label with a tax or a MQS under approach 1 is coincidental, since the participants stopping purchasing products are replaced by the same number of participants purchasing the new labeled product.

(ii) The combination of different instruments improves the welfare and thwarts excessive distortions coming from the use of a sole instrument. For example, for each column, the tax combined with the label (t^{**}) is much lower than the tax alone (t^*). With approach #1 (first column), the tax $t^{**} \geq 0.36$ maximizing the welfare combined with the label leads all the consumers (including the indifferent) to choose the environmentally friendly shrimps (which is equivalent to the label combined with the

[11] Alternative estimations could take the average proportion $(\beta_I+\beta_{II})/2$. Another extension could distinguish between concerned consumers for the polluting product and concerned consumers for the environmentally friendly product, while our theoretical model only considers a similar proportion β of concerned consumers for the environmental characteristics of the polluting and environmentally friendly products.

[12] This result could be modified after taking into account administrative costs of regulation that are not detailed in this paper.

MQS in the last line). With approach #2, the tax $t^{**}= 0.289$ maximizing the welfare combined with the label leads concerned consumers to purchase environmentally friendly shrimps, while indifferent consumers purchase polluting shrimps.

(iii) The combination of the tax and the label is socially-optimal whatever the approaches. The label guarantees the diversity, while the tax internalizes the residual damage of the concerned consumers who would purchase the polluting shrimps because of their lowest price without knowing the damage linked to them.

(iv) The dominance of the combination of a label and a tax is linked to the assumption of a label perfectly known by all consumers and available in every supermarket, which is unlikely to occur in real situations where credible information is hard to convey. Alternatively, under the absence of label, the MQS is socially-optimal compared to the tax whatever the approaches used for computing the welfare. The tax is relatively inefficient since the demand elasticity is relatively low (see table 1) leading to a too low-quantity adjustment for reducing the non-internalized damage. This result is interesting as the tax is generally mentioned in public debates.

(v) Welfare measures vary across the methodologies (in particular for different values of β with approach #2), but the regulatory choice is invariant: the combination of the label and the per-unit tax always leads to the highest welfare variation. This result provides robustness to the selection of instruments based on welfare estimation. However in real situations, the regulator also needs to carefully compare these welfare gains to the cost of regulation and sunk cost for firms. A complete cost-benefit analysis should systematically compute both approaches for understanding the sensitivity of the results when different approaches or assumptions are considered.

Insert table 2 here

6. Conclusion

Environmental regulatory agencies often face intense pressures to act on controversial topics.

However, the toolkit of regulatory options is extensive 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 three policy instruments (per-unit tax, MQS and label) and showed how to link consumers' WTP or preference estimates coming from a lab experiment to welfare effects of regulatory scenarios. Experimental results provide a useful basis to anticipate consumers' reactions and allow regulatory agencies to consider different options in terms of their costs and benefits including market reactions.

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. For instance, the supply side could be developed with increasing supply curves coming from firms/farms with decreasing returns to scale. In this case, equilibrium price would vary with policies and the label adoption by firms/farms could be carefully studied. Moreover, other instruments like a subsidy for developing the label possibly financed by a per-unit tax on the polluting product could be envisioned.

We used two approaches for estimating welfare changes. Each of them has some limitations and using both approaches conveys robustness to the methodology. It would seem prudent to be upfront with decision makers (by computing both methodologies) as to the underlying uncertainty/limits in our ability to quantify the effects of a policy. Despite differences across approaches, our results clearly show the dominance of some instruments and may be precious for guiding public debates.

This methodology supports public debates about the best way to promote efficient policy. 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.

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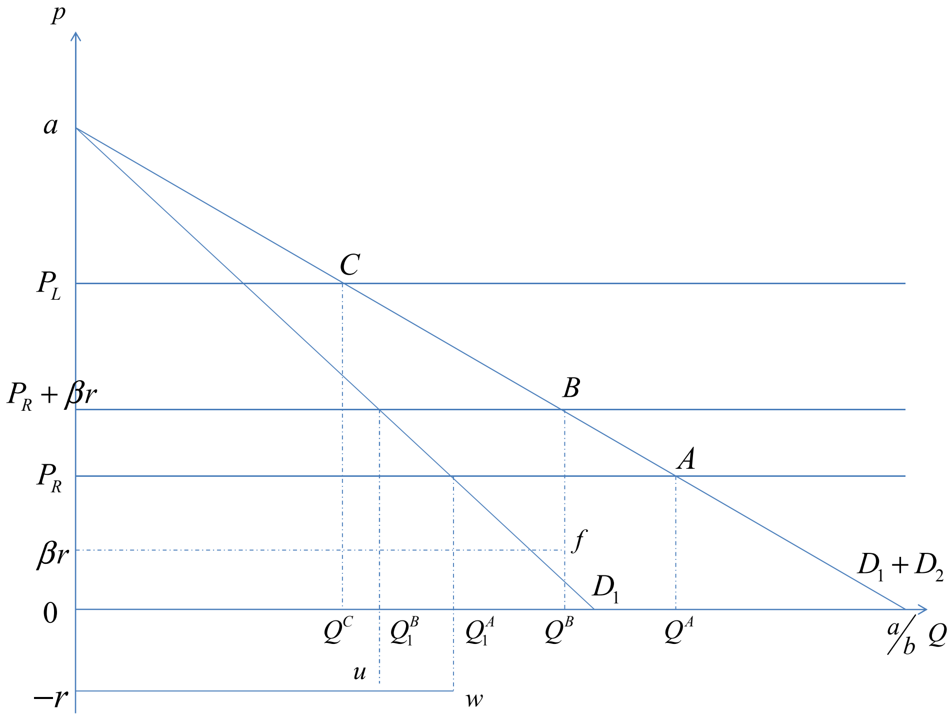

Fig. 1 Baseline (without regulation), per-unit tax or MQS

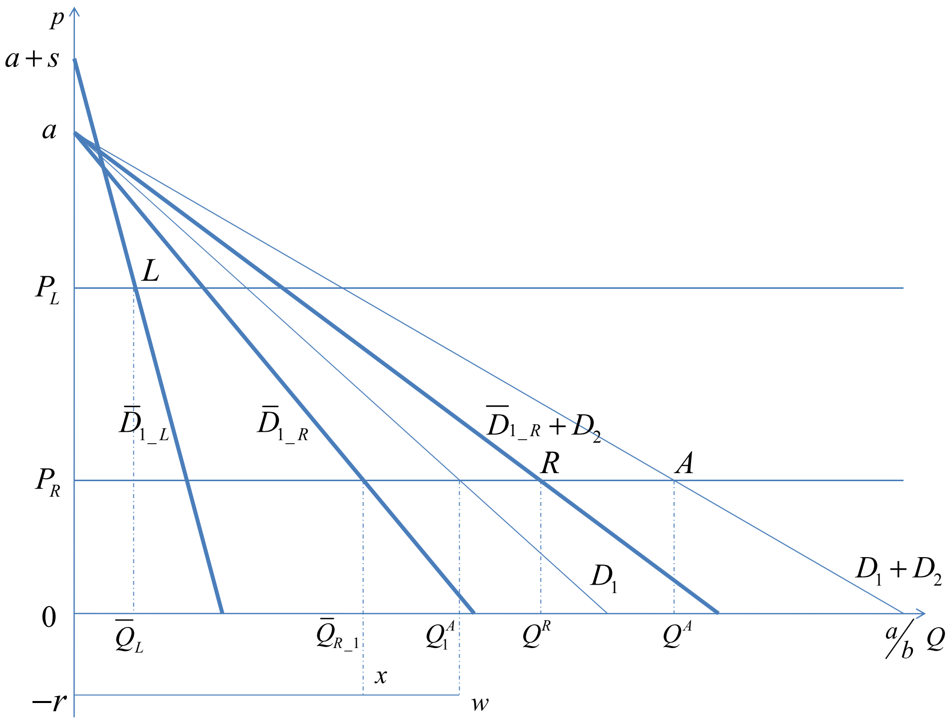
p
a+s
a
P_L
L
$\bar{D}_{1\_L}$
$\bar{D}_{1\_R}$
$\bar{D}_{1\_R}+D_2$
P_R
R
A
D_1
D_1+D_2
0
$\bar{Q}_L$
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Fig. 2 Label

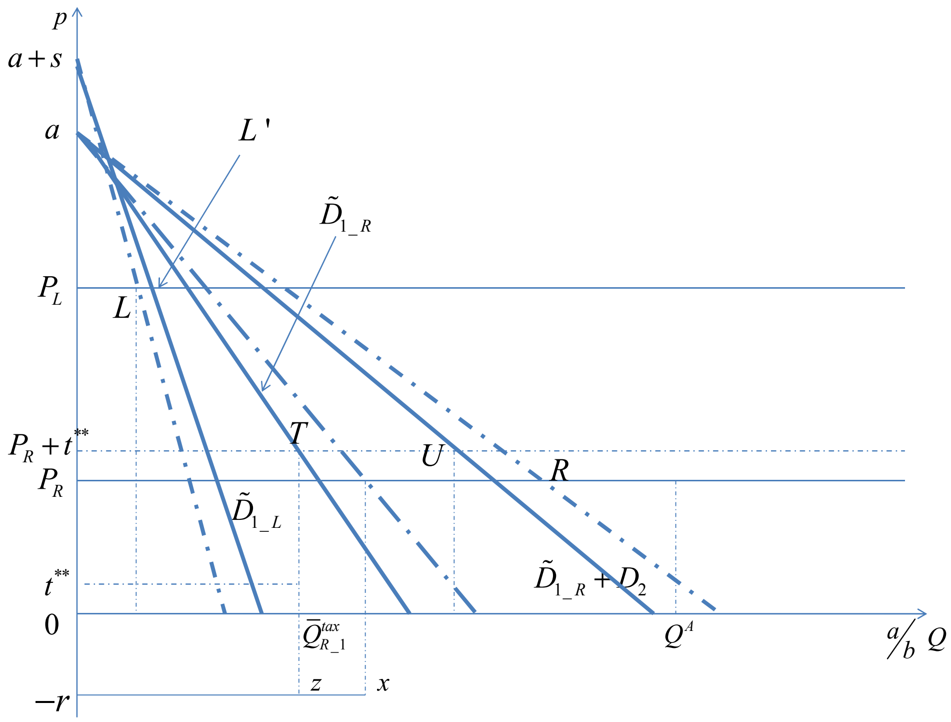


Fig. 3 Label combined with a tax

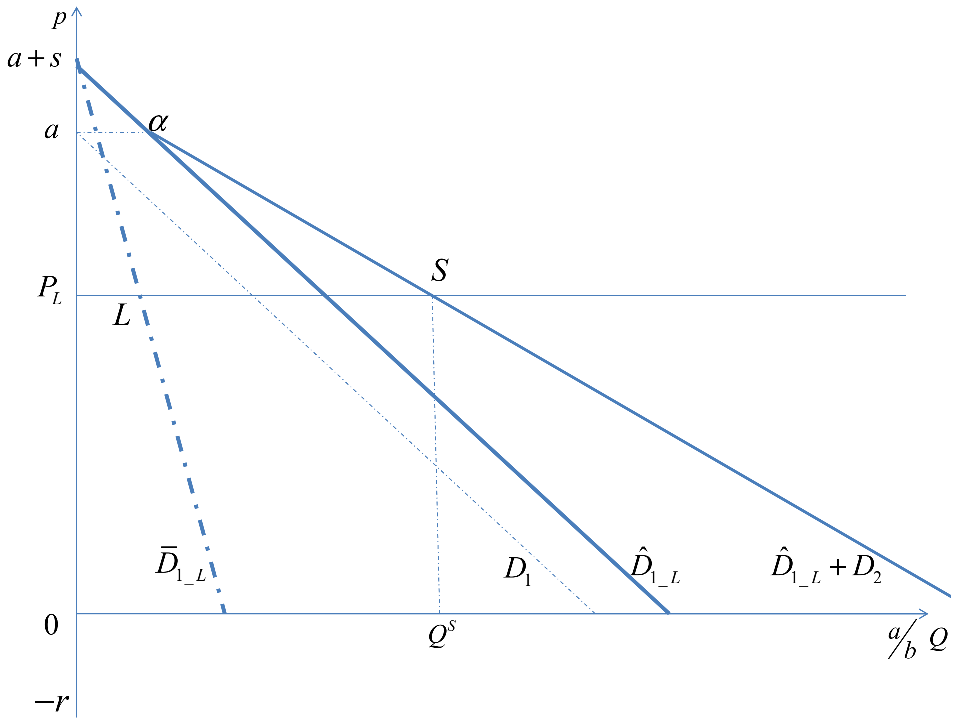
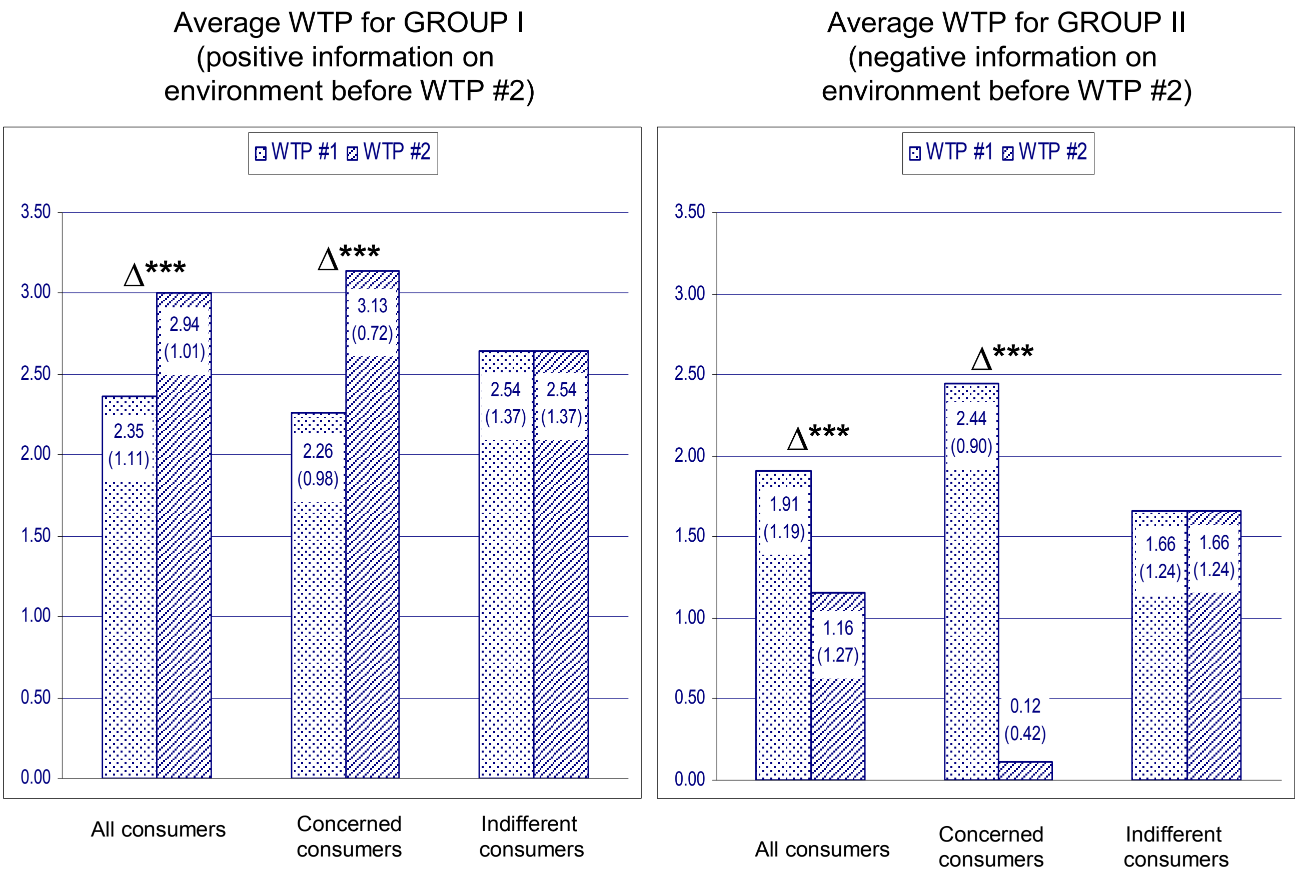


Fig. 4 Label combined with a MQS



Note: WTP in €; Δ*** denotes significant differences at the 1% level as tested by the Wilcoxon test for comparing paired samples.

Fig. 5 Impact of environmental information on WTP

Table 1. Values of parameters for calibrating the welfare variation

Description	Variable	Value
From the experiment		
Relative WTP variation by concerned consumers in group II (%)[a]	δ	- 95.3
Consumers purchasing polluting shrimps with no information (group I)[a] (%)	M	84.6
Consumers purchasing polluting shrimps after the positive info. (group I)[a] (%)	M_1	43.6
Consumers purchasing environmentally friendly shrimps after the positive info. (group I)[a] (%)	M_2	48.7
From time series and observed data		
Consumption of tropical shrimps in 2008 (100g)[b]	$\hat{Q}_R$	565,488,000
Price of polluting shrimps in 2008 (€/100g)[b]	P_R	1.4
Estimated price of environmentally friendly shrimps (€/100g)[c]	P_L	1.75
Own-price elasticity of demand[d]	$\hat{\varepsilon}$	- 0.67

Notes: [a] The relative variation is $\delta = (WTP_2^i - WTP_1^i) / WTP_1^i$. The percentage M (respectively M_1, M_2) is determined by accounting the number of participants whom the surplus CS_1^i defined by (4) is positive (respectively $\max\{WTP_1^i - P_R, WTP_2^i - P_L, 0\}$ with the number M_1 for which $WTP_1^i - P_R$, and the number M_2 for which $WTP_2^i - P_L$ is the maximum).

[b] The notation g denotes the gram. Source: FranceAgriMer (2009). The total consumption of shrimps in France is multiplied by the percentage of shrimps that is tropical (80%) and by the percentage of farmed shrimps (60%).

[c] A price premium equal to 25% is assumed for the shrimps with a label leading to P_L = €1.75. Hervieu (2009) emphasizes that production of environmentally friendly shrimps requires 25% more work than polluting shrimps.

[d] Asche and Bjørndal (2001) for crustaceans in the European Union.

Table 2. **Changes (in value and in percentage) in welfare for different regulatory tools compared to the baseline scenario (without regulation)**

Scenarios	Approach #1	Approach #2 (β_I=0.67)	Approach #2 (β_{II}=0.32)
Per-Unit Tax (€/100g)	t^* = 0.7	t^* = 0.891	t^* = 0.432
Per-unit welfare variation (€/100g)	0.19		
Quantity variation (100g) [a]	-144,996,923 (-26%)	-241,155,185 (-42%)	-116,978,261 (-20%)
Aggregate welfare variation (€)	105,847,753 (+85%)	107,446,692 (+123%)	25,281,926 (+7%)
MQS			
Per-unit welfare variation (€/100g)	0.61		
Quantity variation (100g)	- 101,497,846 (-17%)	-94,719,240 (-16%)	-94,719,240 (-16%)
Aggregate welfare variation (€)	343,497,710 (+276%)	322,561,423 (+371%)	63,087,255 (+18%)
Label			
Per-unit welfare variation (€/100g)	0.70		
Quantity variation (100g)[a]	43,499,076 (+7%)	31,573,080 (+5%)	15,315,300 (+2%)
Aggregate welfare variation (€)	393,376,652 (+316%)	280,904,593 (+323%)	136,259,690 (+39%)
Label + Per-unit Tax (€/100g)	$t^{**} \geq 0.36$	t^{**} = 0.289	t^{**}= 0.289
Per-unit welfare variation (€/100g)	1.05		
Quantity variation (100g)[a]	0 (0%)	-22,541,593 (-3%)	-51,239,680 (-9%)
Aggregate welfare variation (€)	593,617,403 (+478%)	553,575,987 (+637%)	335,259,297 (+96%)
Label + MQS			
Per-unit welfare variation (€/100g)	1.05		
Quantity variation (100g)[a]	0 (0%)	-27,968,486 (-4%)	-62,340143 (-11%)
Aggregate welfare variation (€)	593,617,403 (+478%)	450,964,606 (+518%)	125,372,380 (+36%)

Note: [a] For the per-unit tax, the quantity variation is given by $\hat{Q}_R\left(\sum_{i=1}^{N_P} Z_i' - \sum_{i=1}^{N_P} Z_i\right)/N_P$ for approach #1 (see equations (6) and (7)) and by $Q^B - Q^A$ for approach #2 (see figure 1). The methodology can be replicated for the other scenarios. [b] The sum of polluting and environmentally friendly quantities is taken into account for the equilibrium quantity related to the label scenarios.

Appendix: Revealed information in the experiment

The precise messages are translated from the original French.

The initial information before choice #1

Please read carefully the following information:

"*In what follows we will present you information about farmed, midsize, cooked, shelled and refrigerated shrimps. On the market, the average price for 100g of shrimps varies between €1.50 and €4."*

The environmental information before choice #2

Positive information for group I

"Environmentally friendly shrimps:

In some countries, shrimp producers develop environmentally friendly production scheme.

Discharges are limited and pollution is controlled. Furthermore, the quality of water and ecosystems around the farms is preserved.

These practices, on average, significantly increase the production costs.

These products are sold with a label in France."

Negative information for group II

"Environmental concerns:

Shrimp farms can generate serious environmental problems. In particular, the discharges coming from farms are a source of pollution: deterioration of water quality and of fertility of soils, which were converted into breeding pools.

Given the difficulties and the cost of inspection of imported products, it is likely that the production of a large share of shrimps sold in France generated such pollution."