Taxes, minimum-quality standards and/or product labeling to improve environmental quality and welfare: Experiments can provide answers

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Abstract: This paper focuses on the welfare impact of taxes, minimum-quality standards, and/or product labeling. A theoretical framework shows that the combination of a label and a per-unit tax is socially optimal. Alternatively, if the label is unavailable, the theory cannot directly conclude which instrument should be socially preferred. Estimations of willingness-to-pay (WTP) are useful for completing the theoretical analysis and evaluating policies *ex ante* on case-by-case basis. Using hypothetical WTP for shrimp, we confirm that the combination of a label and a tax is socially optimal. In the absence of a label, simulations show that a minimum-quality standard leads to a higher welfare compared to a tax.

Keywords: Regulatory instruments, environment, stated preference experiment, willingness-to-pay.

JEL Classification C91, H23, Q51.

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1. Introduction

Market failures or the absence of incentives to provide public/private goods lead to sub-optimal choices of quality by sellers. Regulation is then required to guarantee that products provide satisfying attributes for consumers. However, there is no certainty that regulation improves agents' situations because of distortions coming from regulatory instruments. Despite the abundance of theoretical works, no single instrument is clearly superior for improving welfare and guiding policy choices (Goulder and Parry 2008).

This paper compares effects of three main instruments: a per-unit tax on polluting products, a minimum-quality standard (MQS) to reduce pollution and product labeling that is intended to signal products that are environmentally friendly goods. This paper also focuses on the integration of individual estimates of willingness-to-pay (WTP) using partial equilibrium approaches to complete the theoretical analysis of environmental regulatory instruments on a case-by-case basis.

The theoretical framework investigates the welfare impact of each instrument separately and the combined effects of a label with a per-unit tax and a label with a MQS. The theoretical framework shows that the combination of a label and a per-unit tax is socially optimal. Alternatively, if the label is unavailable or if consumers are not familiar with it, the theory cannot directly conclude whether the MQS or the tax is socially optimal. Individual estimates of WTP allow us to precise the choice between instruments. We use the results of a stated preference experiment conducted in France in 2009 that focused on the environmental effects associated with shrimp production in developing countries. Results show that positive environmental information leads to a statistically significant increase in consumers' WTP for shrimp, whereas negative environmental information leads to a statistically significant decrease. Simulations confirm that the combination of a per-unit tax on shrimp production with negative externalities and a label signaling environmentally friendly shrimp production is socially optimal compared to the other instruments. Alternatively, in the absence of a label, the MQS leads to higher welfare compared to the tax.

The impacts of instruments computed in this study provide suggestions for environmental policy. The effects of the chosen instruments are driven by consumers'/citizens' preferences and welfare maximization. This approach is appropriate to complete analyses of environmental policy, which are generally defined by ecological objectives aimed at capping pollution. Our paper follows the lead of Sunstein and Thaler who define the concept of "libertarian paternalism" as attempting "to steer people's choices in welfare-promoting directions without eliminating freedom of choice" (Sunstein and Thaler 2003 p.1159).

This paper adds to the literature by showing that theoretical and empirical frameworks are complementary. We contribute to the theoretical literature on environmental labeling by focusing on the combination of various instruments. We suggest that the role of information/labeling should be examined in relation to other regulatory instruments to evaluate 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 a market failure characterized by an under-investment in one environmental characteristic. This mitigates the classical idea that one market failure only justifies employing one instrument (Goulder and Parry 2008).

This paper also provides an example of how WTP study results may be taken a step further. Many surveys or experimental papers that provide WTP estimates stop short of deriving welfare measures for the policies serving as the impetus for the study (Lusk and Shogren 2007). Some experimental papers address welfare estimations by only focusing on the impact of information revealed in the experiment. This value of information is estimated by Colson et al. (2008), Hu et al. (2005), Huffman et al. (2003 and 2007), Lusk et al. (2005), Lusk and Marette (2010), Marette et al. (2008a, 2008b, 2008c, 2011), Masters and Sanogo (2002), Roosen and Marette (2011), Rousu et al. (2004 and 2007), Rousu and Shogren (2006), Rousu and Corrigan (2008) and Rousu and Lusk (2009). These studies are important for estimating the potential impacts of labeling or public information, but expanding the choice of regulatory instruments may increase the role of experimental data. Beyond the value of information, estimations of impacts coming from MQS and taxes could also help the public debate.

The next section introduces the theoretical framework. Section 3 provides the method used for estimating welfare changes. Section 4 describes the stated preference experiment on shrimp and the environment and details the welfare estimation linked to the different instruments. The last section presents our conclusion.

2. A theoretical model

Public intervention is useful for alleviating market failures that lead to sub-optimal choices by firms and consumers. Without any regulation, the emergence of environmentally friendly products is unlikely. However, the toolkit of instruments available to address sub-optimal choices is rather large. This section introduces a simple theoretical model to determine the welfare effects of three instruments 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).[1] In particular, this model matches issues linked to the stated preference experiment that compares choices between polluting and environmentally friendly shrimp.

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

[1] 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.

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: concerned consumers with a utility impacted by the environmental characteristics of products and indifferent consumers without any sensitivity to the environment. This division fits experiments and surveys, where concerned consumers react to the information with a different WTP, while indifferent consumers do not change their WTP after receiving information about environmental characteristics.

In this simplified framework, two products are available on the market: a regular product that pollutes the environment and an environmentally friendly, labeled product.[2] The characterization of preferences largely follows Polinsky and Rogerson (1983). Demand of each consumer i={1,…,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 $a, b > 0$ 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 associated with 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

[2] 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 labeled environmentally friendly.

'positive' messages, which suits our stated preference experiment. There may be important differences between the two types of messages as consumers may react differently to a negative signal compared to a positive one. The parameter *I* represents the consumers' knowledge regarding the environmental characteristic of the polluting product (the parameter *J* represents their knowledge of the labeled product). If consumers are not aware of the characteristic, then *I*=0 (or *J*=0). However, the characteristic is still accounted for in the welfare via the non-internalized damage.[3] 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 perceive polluting and environmentally friendly products as different when both products are offered, which impacts their utility. Maximizing utility as 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 the 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:

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

Indifferent consumers perceive both products as perfect substitutes with θ=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: $\bar{q}^D_{R\_i}(p_R) = Max\left[0, (a - p_R)/\bar{b}\right]$.

[3] 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.

Individual demands are aggregated by subgroups, which makes sense given the regulatory debate tackled by this paper. It is assumed that a proportion $\beta=N_1/N$ of consumers are concerned with 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 $(1-\beta) = 1-N_1/N$ of consumers are 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: $\overline{Q}^D_{R\_i}(p_R) = \sum_{i=1}^{N-N_1} \overline{q}^D_{R\_i}(p_R) = (N-N_1)\overline{q}^D_{R\_i}(p_R)$.

When both polluting and environmentally friendly products are offered and with $b = \overline{b}/N$, $N_1 = \beta N$ and $(N-N_1)=(1-\beta)N$, the overall inverse demands are:

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

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

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 $P_R < P_L$ because the product that respects the environment is more costly to produce. We assume perfectly elastic producer supply represented by constant returns to scale technology, implying zero producer profits (with an 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 and 2005). Adoption depends on many parameters, such as the retailers' strategy and the contracts with farmers, the possibility to advertise, the existence of other labels, etc. This analytical simplification allows for 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, we assume that regulation is costless. This leads us to study the 5 following regulatory scenarios and to compare them to the absence of regulation: (*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 in 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 in which many participants are not aware of the environmental damage linked to the production of regular polluting shrimp. Figure 1 shows supply and demand. The price is depicted on the vertical axis and the quantity is shown along the horizontal axis.

In the absence of regulation, the supply is represented by P_R. As the production of the polluting product is less costly, the environmentally friendly technology that is not certified is driven out of the market with $Q_L = 0$. The proportion β of concerned consumers is interested in the environmental characteristics 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 are completely indifferent to the environmental characteristics 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 the 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 consumer 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 to ensure 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. A tax t^* equal to βr maximizes the welfare defined by the sum of consumer surplus, the non-internalized damage and the tax income. 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 the area $0(-r)uQ_1^B$, where Q_1^B is the consumption of concerned consumers at price $P_R + \beta r$. The regulator's income from the tax is $\beta r Q^B$ represented by the area $0(\beta r)fQ^B$. Adding the consumer surplus (the area $(P_R + \beta r)Ba$) to the revenue from the tax and subtracting the non-internalized damage yields an overall welfare represented by area $(P_R + \beta r)Ba - 0(-r)uQ_1^B + 0(\beta r)fQ^B$.

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 characteristics. As no information is revealed to consumers, the demand does not change (with *I*=*J*=0), but the non-internalized damage incurred by concerned consumers disappears. The price P_L with unchanged demand leads to the equilibrium *C* and welfare $P_L Ca$.

Figure 1 shows 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 smaller 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.

Regarding the optimal choice between the tax and the MQS, there is no simple theoretical conclusion. In particular, for relatively low values of *r*, the tax provides a higher level of welfare compared to the MQS. For relatively high values of *r*, the MQS provides a higher level of welfare compared to the tax.

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 characteristics of the labeled product.[4] It is also assumed that I=0, which means that consumers stay ignorant about the negative environmental characteristics of the polluting product.[5] In other words, they see the labeled product as an 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. For the ease of 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 lower 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

[4] 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). It is also hard and costly to set up a reputation of credibility.

[5] The alternative case with I=1 could be considered, particularly for crisis situation where the polluting product suffers from a bad collective reputation. When $I=1$ for all consumers, the label alone is socially optimal.

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 $0(-r)x\overline{Q}_{R\_1}$. 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 in 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, as 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 the 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 the area $0(-r)z\overline{Q}_{R\_1}^{tax}$. Welfare is defined by the area $P_L L'(a+s)+(P_R+t^{**})Ua-0(-r)z\overline{Q}_{R\_1}^{tax}$. Welfare comparisons show that the combination of a label and a per-unit tax is socially-optimal. The label allows product diversity, while the tax helps internalize the damage linked to the regular product.

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 the polluting product as a result of the MQS. The overall demand for the labeled product is equal to $\hat{D}_{1\_L} + D_2$, 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*. Welfare is defined by the area $P_L S\alpha(a+s)$. The indifferent consumers will consume the environmentally friendly product, but they would prefer regular products at a lower cost. This scenario therefore leads to a lower welfare compared to scenario #4.

Insert figure 4 here

The label combined with a per-unit tax on regular products improves welfare compared to other tools because product diversity and freedom of choice are beneficial to society. Estimates of WTP are useful for determining the tax level to be imposed on regular products. Conversely, prohibitive labeling costs, imperfect advertising and a high risk of confusion among consumers regarding the significance of the label may lead to the selection of a MQS or a per-unit tax as the socially optimal choice. In this case, there is no clear theoretical conclusion about the optimal instrument to select. Empirical welfare estimates and results from experiments or surveys are important to inform a regulator's choice between a MQS and a per-unit tax. The empirical evaluation of the trade-offs involved is a crucial step for rigorous and convincing cost-benefit analyses.

3. A simple approach for estimating changes in surplus

In this section, we detail an approach for estimating the welfare effects described in figures 1-4 with individual estimates of WTP.

We assume that a consumer purchases a good if his WTP is higher than the price of the good. In the absence of regulation, only the polluting product is available on the market. Consumer *i* can therefore choose between two outcomes: consume a polluting product at price P_R or none. 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 equally divided participants between 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 characteristics 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 $Z_i\left[WTP_2^i - WTP_1^i\right]$, 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 $WTP_2^i \leq WTP_1^i$ for the group receiving the negative information. Recall that concerned consumers are defined by $WTP_2^i < WTP_1^i$, while indifferent consumers are defined by $WTP_2^i = WTP_1^i$. The average per-unit value of the non-internalized damage linked to the polluting product is:

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

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 consumer i's direct surplus CS_1^i, where i belongs to the group with positive information, which determines the overall welfare. In other words, consumers make their decisions 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:

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

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

To measure 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:

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

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:

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

We now turn to the case with a 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 (the polluting product, environmentally friendly product, and none). We assume that consumer *i* is still ignorant about the negative characteristics of the polluting product (*I*=0) and is only aware of the positive information coming from the label for choosing between the three options. The consumer makes a decision based on his surplus $CSD_2^i = \max\left\{WTP_1^i - P_R, WTP_2^i - P_L, 0\right\}$. The non-internalized damage to welfare linked to the polluting product is taken into account with $E(D)$ 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:

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

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

Variations in per-unit welfare can be computed by comparing the level of welfare defined by (7), (8) and (9) to that defined by (6) under the baseline scenario (without regulation). These variations are computed in the following shrimp example.

4. A stated preference experiment of shrimp demand

4.1. The experiment

We conducted the stated preference experiment in Paris, France in December 2009. A total of 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 approximately one hour with participants receiving €15 in compensation. 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 was divided into two groups and participants were randomly assigned to one group. Group I (39 participants) received positive information about the environmental characteristics of the shrimp, while Group II (40 participants) received negative information.[6]

[6] Fisher and Pearson's chi-square tests show that the two groups are not significantly different in terms of socio-economic characteristics (gender, age, education, income, and household composition).

The experiment focused on 100g plastic packages of farmed, midsize, shelled, cooked, and refrigerated shrimp.[7] The inclusion of an environmentally friendly label on the picture of the package of environmentally friendly shrimp was the only way for participants to distinguish between polluting and environmentally friendly shrimp. The experiment elicited hypothetical responses because we did not offer the product at the end of the experiment for two reasons. First, to really measure the marginal value of the environmental characteristics with sequential choices, polluting and environmentally friendly products would have to have been similar across as many dimensions as possible: namely, brand, sauce, weight, packaging, and price. Comparable products of each type did not exist on the French market at the time of the study. Second, the demand for refrigeration made the sale/distribution of products to participants hazardous in terms of food safety. Despite possible hypothetical biases in the WTP elicitations, the study's protocols precisely controlled 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 because the marginal WTP (namely the difference between WTP_2 and WTP_1) is used under the approach presented above. By comparing hypothetical and non-hypothetical responses, Lusk and Schroeder (2004) suggest that marginal WTP for a change in quality/characteristic with food is, in general, not statistically different across hypothetical and real payment settings. By comparing both types of treatments, Taylor et al. (2010) indicate that WTP are not statistically different with private good experiments, but statistically different with public good experiments. Our experiment focuses on food that is a private good. However, as our WTP elicitation method is distinctly different from these two studies, and we have no real-payment experiments to which we can compare our results, we cannot make any definitive conclusions about the presence or

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

magnitude of hypothetical bias in our experiment. As such, we pay close attention to the robustness of simulations to different WTP estimates.

The experiment was divided into several stages sequenced as follows: Participants received general instructions and signed a consent form. They completed an entry questionnaire on consumption behavior and socio-demographic characteristics. Two rounds of WTP elicitation were then organized. In the first round, we provided basic information about the shrimp, including the range of existing prices observed in supermarkets (between €1.50 and €4). No environmental information was revealed in the first round. In the second round, we provided information about possible environmental production conditions linked to shrimp. Recall that during this second round of WTP elicitation, Group I received positive information about environment, while Group II received negative information about environment (see the appendix for the complete messages). Finally, participants completed an exit questionnaire and received the €15 compensation.

A multiple price list was presented on a sheet of paper to elicit participants' WTP. During the two choice phases, participants were asked to choose whether they would buy the 100 g plastic package of farmed, midsize, shelled, cooked, and refrigerated shrimp for prices varying from €0.25 to €4 with a 25 cent interval between possible choices. A color picture of the shrimp package (accompanied by a label for environmentally friendly shrimp) was presented on the paper. As no major brand dominates the market, the private brand (linked to a French supermarket) was concealed to avoid any influence of this supermarket brand. For each price, participants had to check off either "yes", "no", or "maybe" denoting their purchasing preferences. 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" was checked off, we set the WTP to zero. If "yes" was always selected, we set the WTP to €4.[8]

[8] Andersen et al. (2006) underline two disadvantages of the multiple price list. The first disadvantage is that the interval response elicits intervals from participants rather than point estimates for WTP. With our experiment,

The results of the WTP elicitation are the following. First, the initial WTP expressed before the revelation of any environmental information is similar across the two groups (€2.35 for Group I with a 95% confidence interval of [1.99; 2.71] and €1.91 for Group II with a 95% confidence interval of [1.53; 2.29]). Second, participants reacted to the information revelation, and the change in WTP goes in the expected direction: the average WTP expressed by Group I increases from €2.35 to €2.94 (with a 95% confidence interval of [2.62; 3.26] after the revelation of positive environmental information. WTP expressed by Group II decreases from €1.91 to €1.16 (with a 95% confidence interval of [0.76; 1.56]) after the revelation of negative environmental information. For both groups, the average WTP variation is significant at the one percent level as tested by the Wilcoxon test for comparing paired samples.[9] Note that 3 participants slightly decreased their WTP after the revelation of positive environmental information and 9 participants slightly increased their WTP after the revelation of negative environmental information. These unexpected variations may indicate a rejection of the environmental issues by participants. We decided to treat them as indifferent consumers and set their WTP in choice #2 at the same level as in choice #1. Our results are, however, robust whether these answers are included or if these 'inconsistent' answers are dropped from the sample.

4.2. The welfare estimation

Table 1 provides the economic impact of different regulatory tools on welfare. We present the per-unit welfare variation (for 100 g of shrimp) 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 100 g) by $\hat{Q}_R$, the number of times 100 g of shrimp are

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the 25-cent interval provides reasonable precision for the elicited WTP. The other disadvantage is the framing effect with a psychological bias towards the middle of the multiple price list. We do not control for this framing effect. However, the psychological bias is not really plausible in our experiment: only 12.7% of participants express a WTP of €2 in choice #1 and this percentage is even smaller after the second message (e.g. 6.3%).

[9] This non-parametric test is usually used when comparing repeated measurements on a sample to assess whether their population means differ.

consumed over the year in France. According to France AgriMer (2009), French consumption of farmed tropical shrimp in 2008 was 56,548,800 kg and the estimated price of polluting shrimp in 2008 is equal to P_R = €1.4 for 100 g. A possible price premium equal to 25% for shrimp with a label leads to P_L = €1.75.[10] The first column of table 1 directly uses the individual vectors of WTP. The second and third columns test the robustness of our results by correcting individual WTP with the upper- and lower-ends of the 95% confidence interval. This means that for Group I, receiving positive environmental information, each observation WTP_1^i for choice #1 is corrected by $\pm\sigma_1/\sqrt{N_P}$ with σ_I, the standard deviation linked to observations of vector WTP_1 (similarly WTP_2^i for choice #2 is corrected by $\pm\sigma_2/\sqrt{N_P}$). The average per-unit value of the non-internalized damage $E(D)$ given by (5) is also calculated by correcting WTP_1^i and WTP_2^i with the corresponding 95% confidence interval for Group II (receiving the negative environmental information). Welfare variations are computed by taking into account the welfare under a given scenario minus the welfare under the baseline scenario (e.g. without regulation). Four main conclusions could be derived from table 1.

Insert table 1 here

(i) All welfare variations are positive, which means that the regulation increases welfare. This result could be modified after taking into account administrative costs of regulation that are not included. The per-unit tax and the MQS with a higher cost negatively impact the equilibrium quantity. However, welfare increases as 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 welfare because a new segment is created. Eventually, the absence of quantity variation for the scenarios combining the label with a tax or a MQS in column (1) is coincidental, since the participants who stop purchasing products are

[10] Hervieu (2009) emphasizes that the production of environmentally friendly shrimp requires 25% more work than the production of polluting shrimp.

replaced by the same number of participants purchasing the new labeled product.

(ii) The combination of different instruments improves welfare and eliminates 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^{*}). In column (1), the tax $t^{**} \geq 0.36$ maximizing the welfare combined with the label, leads all the consumers (including the indifferent consumers) to choose environmentally friendly shrimp (which is equivalent to the label combined with the MQS in the last line).

(iii) The combination of the tax and the label is always socially optimal. The label guarantees diversity, while the tax internalizes the residual damage of the concerned consumers who would purchase polluting shrimp because of their lower price without knowing the damage linked to them. The dominance of the combination of a label and a tax is dependent on the assumption that a label is perfectly understood by all consumers and is available in every supermarket, which is unlikely to occur in real situations where credible information is hard to convey. Alternatively, in the absence of the label the MQS is socially optimal compared to the tax. The tax is relatively inefficient as demand elasticity is relatively low, leading to a quantity adjustment that is too low to reduce the non-internalized damage. This result is interesting as the tax is generally mentioned in public debates.

(iv) Welfare measures vary in columns (2) and (3), but the regulatory choice is invariant: the combination of the label and the per-unit tax always leads to the greatest welfare. If the label is unavailable, our example shows that the MQS leads to a higher level of welfare than the tax. This result provides robustness to the selection of instruments based on the welfare estimation. Because of possible WTP overestimations with stated preferences, we ran additional simulations with lower WTP compared to column (3). In this column (3), the relatively high welfare variations in percentage are explained by a relatively low welfare for the baseline scenario. As a meta-analysis performed by Murphy et al. (2005) finds a median upward bias of 35% for WTP with public goods, we decrease all our estimated values of WTP by 35% even if shrimp is a private good. Once more the socially optimal instruments are invariant, even if the welfare improvements are of course lower compared to the ones presented in table 1. Works using preference elicitation therefore put a fine point on the policy analysis. However, in real situations, the regulator also needs to carefully compare these welfare gains to estimates of administrative costs and sunk costs for firms.

To complete the robustness analysis, we also estimate welfare changes under an alternative approach. This approach relies on a combination of demand drawn from time-series economics (and determined by classical calibration with price elasticities) and the average WTP value obtained from an experiment. Average WTP is used to calculate the parameters r (per-unit damage) and s (per-unit benefit) defined in (1). For instance, 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 across participants. This relative variation is extrapolated to measure the variation of overall demands defined by (3) leading to an estimated value is $\tilde{r} = -\delta P_R$. Results are relatively similar to the ones obtained with the previous welfare estimation. Methodology and results linked to this alternative approach #2 are available on URL: http://www4.versailles-grignon.inra.fr/economie_publique/content/download/3294/34305/version/1/file/Appendix-JRE-Oct-5.pdf. The regulatory choice is also invariant when welfare variations are computed with scenarios other than the ones presented in table 1.

5. 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 (a per-unit tax, a MQS and a label) and showed how to link consumers' WTP or preference estimates coming from an experiment to the 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. To fit different problems coming from various contexts, some extensions could be integrated. For instance, the supply side could be developed with increasing supply curves coming from firms with decreasing returns to scale. In this case, equilibrium price would vary with policies and the adoption of a label by firms could be carefully studied. Moreover, other instruments (such as a subsidy for developing the label possibly financed by a per-unit tax on the polluting product) could be envisioned.

Our simulation results clearly show the dominance of some instruments and may be important for guiding public debates and cost-benefit analysis. Despite the stated limitations to the methodology, we show that different regulatory choices may be tested *ex ante* in a fashion that renders experiments meaningful for policy makers: an outcome that has been a longstanding challenge for experimental economics.

6. Appendix: Revealed information in the experiment

The precise messages are translated from the original French.

The initial information before choice #1

Please read the following information carefully:

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

The environmental information before choice #2

<u>Positive information for group I</u>

"Environmentally friendly shrimp:

In some countries, shrimp producers develop environmentally friendly production schemes. 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."

<u>Negative information for group II</u>

"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 costs of inspection of imported products, it is likely that the production of a large share of the shrimp sold in France generated such pollution."

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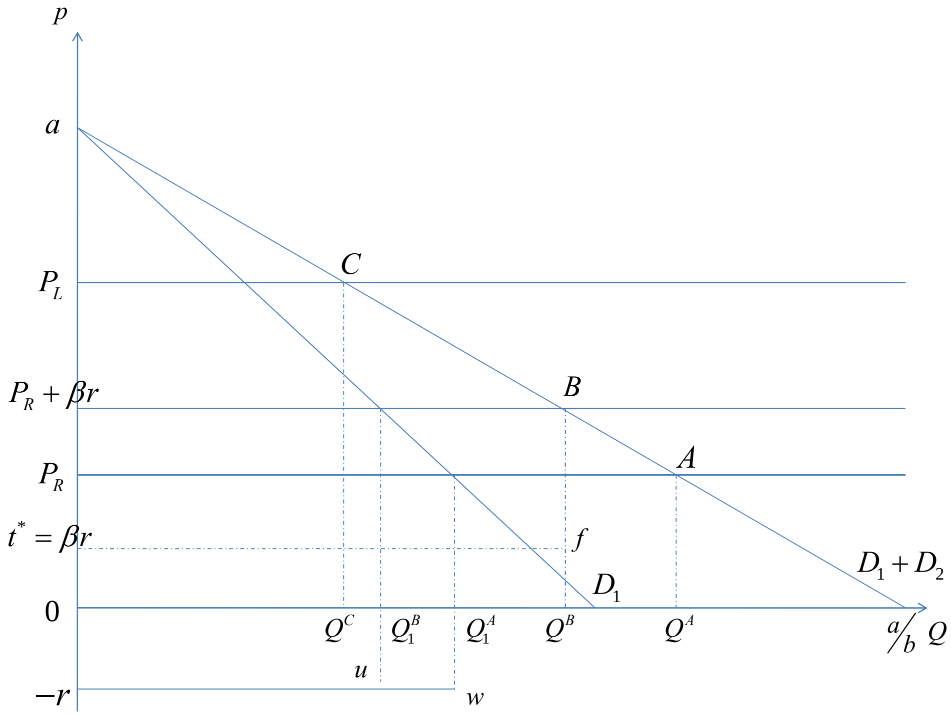
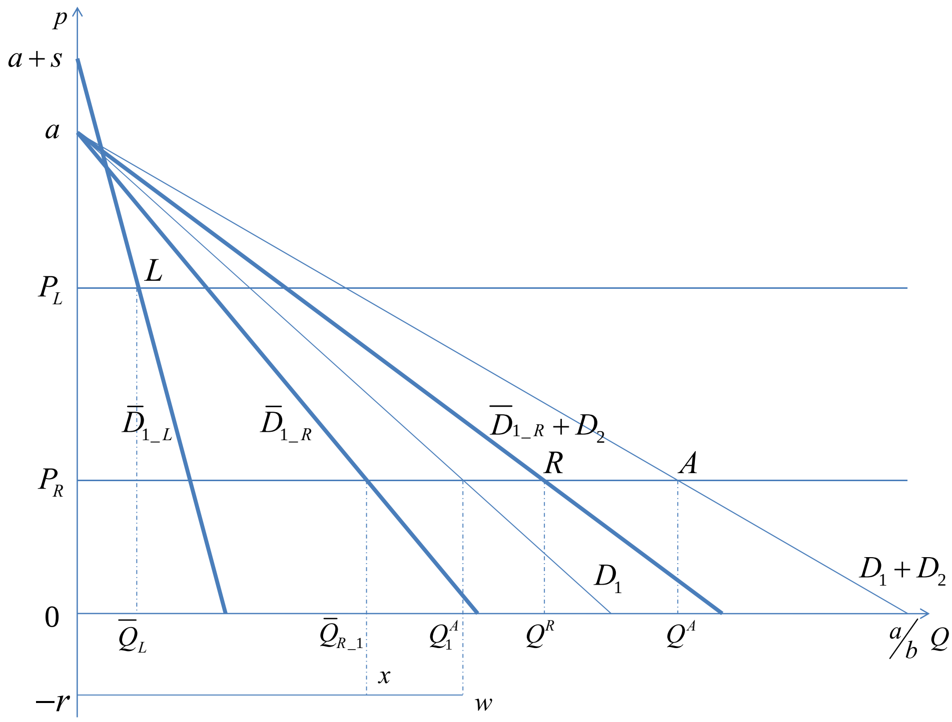


Fig. 1 Baseline (without regulation), per-unit tax or MQS



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P_L
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$\bar{D}_{1\_L}$
$\bar{D}_{1\_R}$
$\bar{D}_{1\_R}+D_2$
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P_R
D_1
D_1+D_2
0
$\bar{Q}_L$
$\bar{Q}_{R\_1}$
Q_1^A
Q^R
Q^A
a/b
Q
x
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w

Fig. 2 Label

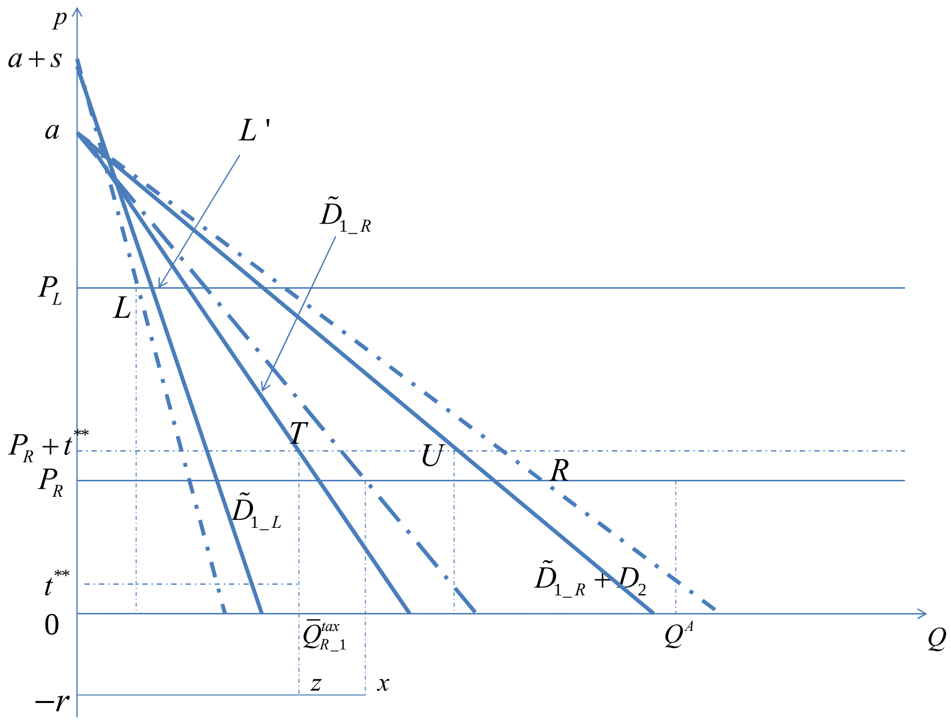

Fig. 3 Label combined with a tax

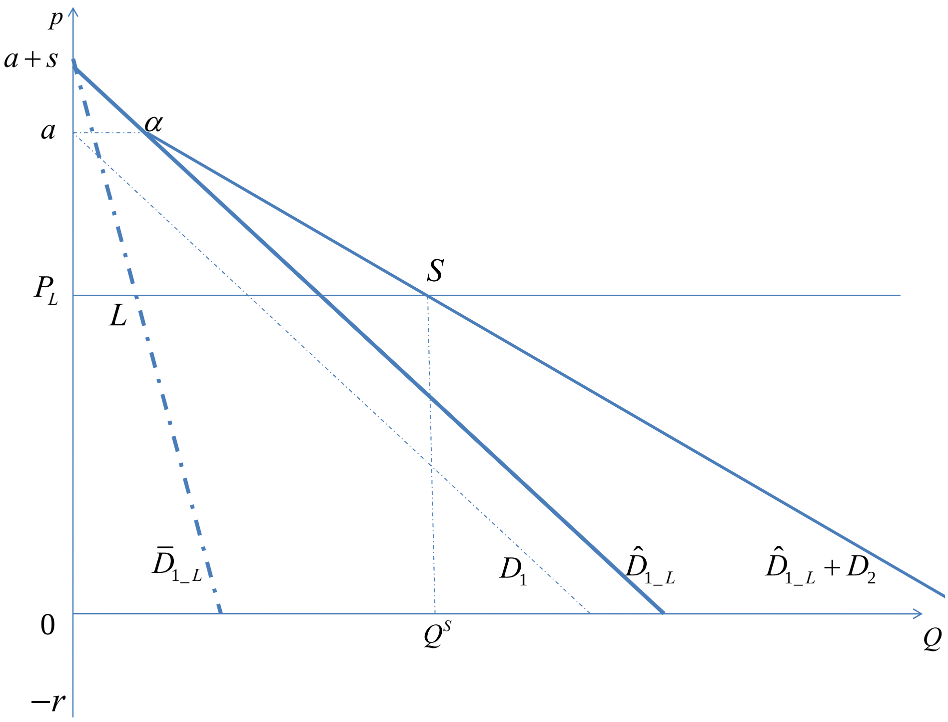

Fig. 4 Label combined with a MQS

Table 1. Changes (in value and in percentage) in welfare for different regulatory tools compared to the baseline scenario (without regulation)

Scenarios	WTP	WTP + $2\sigma/\sqrt{N_P}$	WTP - $2\sigma/\sqrt{N_P}$
Per-Unit Tax (€/100g)	$t^* = 0.7$	$t^* = 0.71$	$t^* = 1.1$
Per-unit welfare variation (€/100g)	0.19	0.07	0.12
Quantity variation (100g)[a]	-144,996,923 (-26%)	-101,497,846 (-17%)	-159,496,615 (-28%)
Aggregate welfare variation (€)	105,847,753 (+85%)	42,890,089 (+12%)	69,685,521 (+128%)
MQS			
Per-unit welfare variation (€/100g)	0.61	0.51	0.50
Quantity variation (100g)	- 101,497,846 (-17%)	0 (0%)	-43,499,076 (-7%)
Aggregate welfare variation (€)	343,497,710 (+276%)	287,093,907 (+86%)	283,584,982 (+520%)
Label			
Per-unit welfare variation (€/100g)	0.70	0.68	0.61
Quantity variation (100g)[a]	43,499,076 (+7%)	57,998,769 (+10%)	57,998,769 (+10%)
Aggregate welfare variation (€)	393,376,652 (+316%)	385,604,817 (+115%)	348,340,608 (+639%)
Label + Per-Unit Tax (€/100g)	$t^{**} \geq 0.36$	$t^{**} \geq 0.39$	$t^{**} \geq 0.31$
Per-unit welfare variation (€/100g)	1.05	0.96	0.9
Quantity variation (100g)[a]	0 (0%)	57,998,769 (+10%)	43,499,076 (+7%)
Aggregate welfare variation (€)	593,617,403 (+478%)	546,870,395 (+164%)	513,405,105 (+943%)
Label + MQS			
Per-unit welfare variation (€/100g)	1.05	0.96	0.9
Quantity variation (100g)[a]	0 (0%)	57,998,769 (+10%)	43,499,076 (+7%)
Aggregate welfare variation (€)	593,617,403 (+478%)	546,870,395 (+164%)	513,405,105 (+943%)

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