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Should the regulator allow citizens to participate in tradable permits markets?

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Abstract

Since the seminal paper written by Weitzman (1974), the "prices vs. quantities" debate regarding choice of policy instrument under imperfect information and uncertainty has been an ongoing concern for economists, especially in the field of the environment. In this debate, several papers have recommended that the regulator allow pollution victims (citizens) to participate in tradable permits markets. According to this literature, when pollution victims purchase and withhold (i.e. destroy) emission rights from polluting firms, this means that the overall quota is not efficient and that welfare gains will be realised. In this paper, we present further theoretical results showing that citizen participation in tradable quotas markets may become welfare decreasing. Indeed, citizens can aggravate the first error made by the regulator if they are also under uncertainty about the marginal benefit curve or if they exhibit strong enough risk aversion. Therefore, we recommend that the regulator limit citizen participation to a certain percentage of permits. In doing so, we extend the "prices versus quantities" debate to simultaneous uncertainty and risk aversion by showing that a marketable permits system offers the regulator an opportunity to control the negative effects of agents' (citizens' and firms') risk aversion on welfare.

Keywords: citizen participation, emissions trading, prices vs. quantities, risk aversion.

JEL Classification: Q50.

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1 Introduction

Since the seminal paper written by Weitzman (1974), the "prices vs. quantities" debate regarding choice of policy instrument under imperfect information and uncertainty has been an ongoing concern for economists, especially in the field of the environment. In the presence of significant uncertainty about the benefits and costs of environmental protection, the "prices vs. quantities" literature establishes the conditions under which price-based environmental regulation (emission tax) or quantity-based environmental regulation (command-and-control or tradable permits[1]) is the preferred policy. The main finding is that expected welfare gains generated by both instruments depend on the relative slopes of the aggregate functions of marginal pollution abatement cost and marginal benefit of pollution control[2].

In this debate, one of the latest theoretical refinements is to include the victims of pollution (or environmental groups), hereinafter referred to as "citizens", in the tradable permits market. It should be noted that this policy recommendation of including pollution victims in pollution permits markets was first developed by Dales (1968) but did not attract attention until Shrestha (1998). According to this article, if the pollution level defined by the regulator under uncertainty exceeds the optimal pollution level, then citizen participation in pollution permits market is a means of reaching the optimal pollution level by purchasing and retiring "bad" permits from the market. Following Shrestha, several papers have considered the participation of pollution victims in the trading process (Ahlmein and Schneider 2002; Smith and Yates 2003a,b; Malueg and Yates 2006; English and Yates 2007; Israel 2007; Rousse 2008). As a whole, these papers confirm Shrestha's findings in concluding that citizen participation in emissions trading should not be prevented. They suggest that when non-polluting agents buy and destroy permits, this means that the overall quota is not efficient and therefore welfare gains will be realised.

In practice, regulators follow this policy recommendation and generally allow any artificial or natural person to access the emissions markets (SO_2 Acid Rain Program, RECLAIM Program, European Union CO_2 Emissions Trading Scheme[3]). At present, citizens are not proactively participating in emissions trading[4], probably due of high transaction costs and being unaware of this opportunity rather than because optimal levels of pollution have been set by regulators. But as the demand of individuals wishing to take part in the environmental policy grows (Brewer 2005) and utilization of market mechanisms for the purpose of environmental protection becomes increasingly accepted, especially in the fight against climate change with the recent success of carbon offsetting[5], citizen participation in pollution permits markets appears to be the next step towards a more participative environmental policy. Indeed, public participation in decision-making is now a commonly stated objective across most sectors of environmental policy (Few et al. 2007), and citizen participation in emissions trading (market participation) implies a higher degree of active involvement in taking decision than traditional (non-market) forms of public participation (forming interest groups, demonstrating, lobbying).

In this paper, we present further findings on the theoretical justification of citizen participation in emissions trading and show that Shrestha's proposition does not necessarily hold, for two reasons. First, in practice, citizens are generally not better informed than the benevolent regulator about the marginal benefit curve. Second, because of the uncertainty citizens are faced with, it is reasonable to assume that they may exhibit risk aversion, for instance, regarding the benevolent nature of the regulator or simply regarding the severity of the environmental and economic effects of pollution. In these theoretical frameworks, we show that citizen participation in pollution permits market can either increase or decrease the level of welfare. As the effects of risk aversion in the "prices versus quantities" literature were only addressed by Adar and Griffin (1976) at the polluters' level, our analysis also contributes to this debate by considering the case in which both firms and citizens are risk averse. In this theoretical setting, a marketable permits system will again prove superior to an emission tax because the negative effects of agents' risk aversion on welfare can be controlled by the regulator through the choice of an emission permits market.

Our paper is set out as follows. In the first instance, we review the necessary background for our discussion, i.e. the main conclusions of the prices versus quantities debate when uncertainty is only at the agency level. We then relax the general assumption of perfectly informed and risk neutral citizens. In the second instance, we consider the fact that there is also uncertainty at the citizen level; and in the third instance, we examine the effects of citizens' risk aversion on permit purchasing and withholding behaviour. Finally, we conclude our paper with some policy recommendations.

2 Previous literature

The pollution control agency faces significant uncertainties regarding both the costs and benefits of environmental protection. Concerning costs, we can say that pollution control technology is continuously improving (through innovation, economies of scale or learning-curve phenomena), technology diffusion rates are uncertain and future input prices are unknown. As a consequence, the regulator faces uncertainties about individual firms' marginal cost functions and by extension the aggregate marginal cost function. On the other hand, the environmental protection agency also faces uncertainties about the marginal benefit function. Indeed, the standard error attached to the marginal benefit function is significant because environmental effects of pollution are generally not well-known, economic effects of pollution (for example on health or land use) are hard to evaluate, and for a given level of pollution, particular weather conditions (high temperature, wind speed, precipitation, etc.) occurring stochastically can have a non-uniform impact on the environmental and economic effects of pollution.

Because of these uncertainties, the regulator is obliged to select an environmental policy knowing that he will make errors. Thus, any environmental policy in the face of uncertainty aims at maximizing expected welfare. In the standard analysis, we assume situations where there is only benefit uncertainty or only cost uncertainty. According to the works of Weitzman (1974), Adar and Griffin (1976) or even Baumol and Oates (1988), the risk neutral regulator chooses the less welfare decreasing instrument according to the relative marginal cost and marginal benefit function slopes. Indeed, with linear approximations of marginal benefit and marginal cost functions[6], Weitzman has established that the comparative advantage of a price instrument over a quantity instrument is given by $\Delta_{p/q} \approx \frac{\sigma_C^2 B''}{2C''^2} + \frac{\sigma_C^2}{2C''}$ which can also be written as follows:

$$\Delta_{p/q} \approx \frac{\sigma_C^2}{2C''}\left(B'' + C''\right)$$

where $\Delta_{p/q}$ is the net welfare advantage of a price instrument over a quantity instrument, σ_C^2 is the variance of costs, $C'' > 0$ is the slope of the marginal cost function, $B'' < 0$ is the slope of the marginal benefit function ($\approx$ refers to an accurate local approximation in the traditional Taylor theorem sense). In order to interpret this result, we generally refer to the graphical representations proposed by Adar and Griffin (1976) where MC is used for marginal cost, MB for marginal benefit, subscript E for expected (anticipated, hypothesized) and subscript R for real (realised, actual, true).

Firstly, when there is complete certainty concerning cost, the standard analysis concludes that benefit uncertainty has no effect on efficient instrument choice: if $\sigma_C^2 = 0$ then $\Delta_{p/q} \approx 0$. This situation is depicted in figure 1 where MC_R is known with certainty. When there is only benefit uncertainty, both instruments achieve the same emission level (Q_E) and, as a consequence, the same welfare loss (area ABC) compared to the efficient emission level Q^*. Secondly, when there is only cost uncertainty, we have to look at the marginal cost and marginal benefit functions slopes. The price instrument is to be favoured ($\Delta_{p/q} > 0$) when $|B''| < |C''|$, and the quantity instrument is to be favoured ($\Delta_{p/q} < 0$) when $|B''| > |C''|$. This latter case is depicted in figure 2 where MB_R is known with certainty and the welfare loss under a price instrument is higher than the welfare loss under a quantity instrument (area ABC > area ADE). The intuition behind this is that when the marginal benefit function is steep, i.e. if there are environmental thresholds above which a small increase of emissions can generate highly significant impacts on the environment, it is very important to control quantities strictly in order to ensure that emissions do not exceed the critical level. In the other case, if the slope of the marginal cost is higher than the slope of the marginal benefit, this means that marginal cost will become increasingly high with respect to the damage that is being prevented. In these conditions, price-based regulation is to be favoured compared to quantity-based regulation because if an excessively strict ceiling is determined for quantities, this may generate excessively high constraints for regulated firms.

Leaving aside the standard analysis, let us consider that the regulator faces both cost and benefit uncertainty. The equation corresponding to this situation was provided in a footnote by Weitzman (1974) and re-examined later by Stavins (1996). In this simultaneous uncertainty scenario, the choice of policy instruments depends on the slope of the two marginal functions, but also on their correlation. The comparative advantage of a price instrument over a quantity instrument is now given by $\Delta_{p/q} \approx \frac{\sigma_C^2 B''}{2C''^2} + \frac{\sigma_C^2}{2C''} - \frac{\sigma_{BC}^2}{C''}$ which can also be expressed as follows:

$$\Delta_{p/q} \approx \frac{\sigma_C^2}{2C''}\left(B'' + C''\right) - \frac{\rho_{BC}\sigma_B\sigma_C}{C''}$$

where σ_{BC}^2 is the covariance of benefits and costs, σ_B and σ_C are the standard deviation of benefits and costs respectively, and ρ_{BC} is the coefficient of correlation between benefits and costs.

Based on this equation, we can make the following observations. First, when there is a correlation between benefits and costs ($\rho_{BC} \neq 0$), benefit uncertainty has some effect on instrument choice[7]. Second, a negative correlation between benefits and costs ($\rho_{BC} < 0$) tends to favour the price instrument. Third, a positive correlation between benefits and costs ($\rho_{BC} > 0$) tends to favour the quantity instrument. Fourth, for particular values of different parameters, the results obtained under the standard analysis can be reversed. The probability that the right hand side of the equation may change the sign of the left hand side of the equation is greater when the correlation between benefits and costs is strong, the degrees of benefits and costs uncertainty are high and the marginal benefit function is flat. In figure 3, we give an example of an overwhelming result in favour of the quantity instrument where the marginal cost function is steeper than the marginal benefit function (but remains relatively flat) and there is a positive correlation between benefits and costs (the two realised functions shift in the same direction). In this case of simultaneous uncertainty, the welfare loss under a price instrument is higher than the welfare loss under a quantity instrument (area ABC > area ADE). Fifth, Stavins carries out a simple sensitivity analysis to explore the consequences for efficient instrument choice with plausible values of the relevant parameters (B''/C'', ρ_{BC} and σ_B/σ_C). He shows that the usual policy instrument choice based upon relative slopes alone is less likely to be reversed in the case of conventional identification of a quantity instrument than in the case of conventional identification of a price instrument. Finally, Stavins argues that in practice, cases of positive correlations between marginal benefits and marginal costs are general, suggesting that quantity instruments would be more attractive than otherwise. This tendency in favour of the use of a quantity instrument is also an underlying conclusion in the works of Adar and Griffin (1976) and Shrestha (1998).

At the end of their paper, Adar and Griffin (1976) analyse the consequences of uncertainty and risk aversion at the firm level. In compliance with the theory of the competitive firm under price uncertainty (Sandmo 1971), they find that the risk averse firm will not operate as under risk neutrality where its expected marginal cost equals the expected price. Under quantity regulation, when the price of permits is uncertain, the risk averse firm will produce the output where the expected price is above marginal costs: $E(\tilde{p}) > C'(Q)$, with $\tilde{p}$ being a random variable. Under price regulation, when marginal costs are stochastic, the risk averse firm will operate where the expected marginal cost is less than the price of the tax: $p_T > E[C'(Q, \tilde{\eta})]$, with $\tilde{\eta}$ being a random variable. On the basis of these results, we can say that under quantity regulation, the welfare loss remains the same. On the contrary, under price regulation, risk aversion results in less emission reduction and thus leads to a welfare loss change. This effect is depicted in figure 3 where the marginal cost curve MC_F, representing the firm's behaviour, shifts to the left of the regulator's expected marginal cost function which describes the relevant expected social cost for the risk averse firm. So under a price instrument we reach a lower abatement level ($Q_F < Q_{E'}$) and an altered welfare loss that can become very significant depending on the degree of risk aversion (area AHI > area ABC). In other words, the regulator should take risk aversion among firms into account when choosing a price regulation.

Shrestha (1998) also shows in a different way that a pollution permits market has a certain advantage over an emission tax. She argues that the consequences of the regulator's assessment errors when determining the overall quota can be limited by revealing the preferences of pollution victims. Theoretically, when marginal pollution damage exceeds marginal pollution abatement cost, citizens will participate in emissions trading, i.e. they will purchase and withhold (i.e. destroy) emission permits from polluting firms until the optimal pollution level is reached[8]. For example in figure 1, citizen participation allows the optimal level of pollution (Q^*) to be attained by purchasing and retiring a certain number of $Q_E - Q^*$ permits from the market. In the conventional analysis, it seems that a tradable emission permits system is to be preferred except when the marginal abatement cost curve is steeper than the marginal benefit curve and when its realised position is higher than its expected position.

In the following, we show that citizen participation in emissions trading can in some circumstances lead to higher welfare loss than the absence of citizen participation. Our argument is that the underlying assumptions in previous literature of well-informed and risk neutral citizens are unrealistic. Therefore, we consider in the first instance that on the whole, citizens are under uncertainty about the benefits of pollution control, and in the second instance, that citizens can also exhibit risk aversion. We thus extend the "prices versus quantities" debate to the case of simultaneous uncertainty and risk averse agents (firms and citizens).

3 Uncertainty at the citizen level

Our argument is that Shrestha (1998) and others make a misplaced assumption concerning the timing of uncertainty resolution and the information that citizens have at their disposal.

Shrestha argues that when the environmental target is too lenient, the simple revelation of citizens' preferences for the environment is enough to attain the optimal pollution level. Furthermore, the increasing number of players in the tradable permits market improves competition, as anticompetitive behaviours (market power) from citizens seem improbable[9]. This theory sounds like good news for regulators because if it is true they would simply need to set a deliberately low environmental target and wait for citizens to purchase and destroy bad permits. Unfortunately, this argument is not sufficient. Firstly, citizens can adopt strategic behaviours, i.e. they can free ride by leaving other people to control pollution (Ahlmein and Schneider 2002; Smith and Yates 2003a,b). Secondly, the situation that Hardin (1968) has called "tragedy of the commons" must not arise; i.e. victims of pollution must not be discouraged by the assumed insignificance of their individual actions to reduce the pollution level (Ahlmein and Schneider 2002). Thirdly, high transaction costs can discourage citizens from participating in the trading process (Israel 2007; Rousse 2008). Indeed, in practice, access to these markets is difficult because emissions markets are insiders' markets. On these specific markets, emissions are not as easy to trade as, for example, quoted shares on equity markets[10]. These three remarks reduce the scope of this policy recommendation but do not mean that regulators must prohibit citizen participation in emissions trading since a small degree of participation can always improve welfare.

On the contrary, we believe that citizen participation can become damaging for welfare if we consider that pollution victims can buy and retire too many permits. The possibility that citizens can over reduce pollution has only been considered by Ahlmein and Schneider (2002) and Israel (2007). They mention that agents' preferences can be biased by impurely altruistic behaviours. This concept was introduced for the first time in the economic literature by Andreoni (1989, 1990). In our context, it means that individuals could retire permits in order to feel better by acting as conscientious citizens. The authors indicate that impurely altruistic behaviours should be relatively insignificant and can in part compensate the problems of the commons and of free riding. Thus, they conclude that the regulator should allow citizens to purchase and retire as many pollution permits as they wish.

Our argument is quite similar to the outcome of impurely altruist behaviours but we believe that significance of these combined potential negative effects can be high enough to recommend that the regulator restrict citizen participation in pollution permits markets to a certain number of quotas. Indeed, it is hard to believe that citizens have the correct information about the position of the realised marginal benefit curve and will therefore retire the optimal amount of permits. This assumption of perfect information is unrealistic in practice because the future benefits of pollution control are generally hard to evaluate for the regulator and also for the victims of pollution. So, it is surprising that previous literature supposes benefit certainty on the citizens' side because benefit uncertainty is a common assumption in the literature. As Stavins (1996) points out, "even a casual reading of the environmental economics and environmental policy literatures will suggest that benefit uncertainty is ubiquitous". As Pindyck (2007) also states, "(. . .) we never really know what the benefits from reduced environmental damage will be, (. . .). Worse yet, we can't know with much precision what those benefits will be, even if we work very hard to find out." Furthermore, "more often than not, it is benefit uncertainty that seems to be of substantially greater magnitude" (Stavins 1996).

In general, environmental phenomena are identified but their exact consequences in the future are subject to uncertainty due to the availability of scientific knowledge, stochastic conditions (temperature, wind speed, amount of water and water flow speed, etc.) and also because we do not know how humans will adapt (e.g., by changing eating habits, by building different houses or even by living in new areas)[11]. Thus, we do not see how citizens can be better informed than the regulator and we may even consider that the environmental protection agency generally has superior scientific knowledge compared with pollution victims. For example, in the cases of climate change (greenhouse gas emissions) or even acid rain (SOx and NOx emissions), everybody agrees with the fact that they are bad things but nobody can state exactly how bad they are for the environment (health, land use, species, etc.) and economic activity (agriculture, tourism, etc.). We acknowledge that citizens are better-informed than the regulator about their willingness to pay for the environment, but the problem is that citizens will generally reveal a willingness to pay for something about which they only have a vague idea. It is also worth noting that environmental problems often involve very long time scales (for instance, climate change, nuclear waste, extinction of a species) and irreversibility effects which exacerbate the benefit uncertainty of pollution control.

Since in reality citizens' decision regarding the quantity of pollution permits to be retired is taken prior to the realisation of the damage, their willingness to pay for the environment has to be determined in relation to an expected marginal benefit function. Thus, citizens face the same problem as the benevolent regulator and will purchase and destroy pollution permits under uncertainty in order to maximize expected welfare. To understand the effect of the uncertainty citizens are faced with, we return to our set of simple diagrams presented above, where MB_C refers to the citizens' expected marginal benefit function.

In figure 1, if citizens know with certainty the true marginal benefit function (MB_R), citizen participation in emissions trading allows the optimal level of pollution to be reached. If citizens expect that the position of the marginal benefit function MB_C is between points B and D, then citizens participation in emissions trading reduces or equals the initial welfare loss resulting from the regulator error (notice that areas ABC and ADE are equal). If citizens' expected marginal benefit function is on the left of point B, they will not purchase and retire permits. Finally, if citizens' expected marginal benefit function is on the right of point D, citizens will purchase and retire so many permits that they increase the initial welfare loss. This latter case is depicted in figure 1 where the additional welfare loss corresponds to the area DFGE which can become extremely high for a marginal benefit function shifting well above point D.

In figure 2, we depict a case where citizens will theoretically not retire permits in Shrestha's analysis because the quota set by the regulator is higher than the optimal pollution level. In addition, the initial welfare loss under price regulation is superior to the initial welfare loss under quantity regulation. By applying the same reasoning as in figure 1, we see that for a citizens' expected marginal benefit function MB_C between points D and F, the initial welfare loss under a quantity regulation rises. This increase can be such that it can exceed the initial welfare loss obtained under an emission tax for a shift of the function above point F (notice that areas ABC and AFG are equal). This additional welfare loss is represented by the area FHIG.

In figure 3, we show that our proposition still holds in the case of simultaneous uncertainty in benefits and costs previously examined by Stavins (1996). As explained above, citizen participation can worsen the initial situation to the extent that the initial advantage of quantity regulation above price regulation is reversed. Worse yet, the citizens' expectation error can in theory lead to unlimited welfare loss.

Given this, it appears that Shrestha's proposition applies to a small number of particular cases where pollution victims know with certainty the marginal benefit of pollution control. Generally, these cases concern particular activities where the social costs do not depend on variables beyond the control of those directly involved (polluters and pollution victims). Examples of this are airport noise, olfactory nuisance or traffic congestion[12], i.e. problems where pollution victims are able to measure the real benefit from pollution control precisely. But it is worth noting that in reality, citizens can only fairly accurately measure the benefit from pollution control because we can always find variables which are beyond the control of polluters and citizens. For example, over a particular period, the wind direction can affect the intensity of olfactory nuisances and airport noise, or sunny days can affect the nuisance arising from traffic congestion. This remark also raises the problem of time, or more precisely, the problem of the length of the compliance period. Indeed, if the compliance period includes several pollution periods, action by citizens on the pollution permits market will not be sufficient to avoid hot spots, even if citizens acquire critical information after the environmental target has been set. For example, in cases of olfactory nuisance, a one month compliance period does not allow citizens to reduce pollution externality during a week of unfavourable wind conditions. Another example is the NOx Budget Program in California where the one year compliance period does not avoid hot spots during hot summers.

In the following, we relax another assumption in Shrestha's paper: the hypothesis of risk neutral citizens. We show that the negative effects on welfare of citizens' expectation error about the marginal benefit can be reinforced if citizens also exhibit risk aversion.

4 Uncertainty at the citizen level and risk aversion

In this section, we consider that citizens are under uncertainty about the marginal benefit of pollution control and are also risk averse. Considering the peculiar nature of the good being consumed by citizens (protection of the environment), it is reasonable to assume that they may exhibit a certain degree of risk aversion[13], for instance, regarding the severity of the damage from pollution or even regarding the benevolent nature of the regulator. In this theoretical setting, we show that citizens retire more permits under risk aversion than under risk neutrality.

Our finding is based on Sandmo's seminal paper about the behaviour of a competitive risk averse firm under price uncertainty (Sandmo 1971). In his paper, Sandmo demonstrates that under uncertainty, a risk averse firm will produce output where the expected price of output exceeds marginal cost ($\bar{p} > C'(Q)$). In other words, a risk averse firm produces less than the expected profit maximizing level. Our situation is the opposite of that of Sandmo, as it concerns risk averse consumers who are under uncertainty about the marginal benefit of their consumption.

In compliance with the "prices vs. quantities" framework, we follow the standard convention that goods are desirable and choose to talk about pollution abated (for instance, clean air or pure water) rather than pollution emitted. Thus, we consider a commodity Q that can be produced at cost $C(Q)$ and yielding benefit $B(Q)$ with $C''(Q) > 0$, $B''(Q) < 0$, $B'(0) > C'(0)$ and $B'(Q) < C'(Q)$ if Q is sufficiently large[14]. Citizens are assumed to be under incomplete knowledge and uncertainty about the marginal benefit of pollution reduction. Assuming that citizens have a well-behaved standard Von Neumann and Morgenstern utility function ($U' > 0$ and $U'' < 0$, concavity indicating risk aversion), they maximize their expected utility of welfare, denoted $\tilde{W}$, with respect to Q:

$$\underset{Q}{\text{Max}}\ EU\left(\tilde{W}\right) = EU\left[B\left(Q,\tilde{\theta}\right) - pQ\right]$$

where $\tilde{\theta}$ is a disturbance term or random variable which is unknown at the present time. The first-order condition is:

$$H = \frac{\delta EU}{\delta Q} = E\left[U'\left(\tilde{W}\right)\left(B'\left(Q,\tilde{\theta}\right) - p\right)\right] = 0$$

The second-order condition is:

$$D = \frac{\delta^2 EU}{\delta Q} = E\left[U''\left(\tilde{W}\right)\left(B'\left(Q,\tilde{\theta}\right) - p\right)^2 + U'\left(\tilde{W}\right)B''\left(Q,\tilde{\theta}\right)\right] < 0$$

As the second-order is satisfied, the first-order condition can be written as:

$$E\left[U'\left(\tilde{W}\right)p\right] = E\left[U'\left(\tilde{W}\right)B'\left(Q,\tilde{\theta}\right)\right]$$

Subtracting $E\left[U'\left(\tilde{W}\right)EB'\left(Q,\tilde{\theta}\right)\right]$ from both sides, we obtain:

$$E\left[U'\left(\tilde{W}\right)\left(p - EB'\left(Q,\tilde{\theta}\right)\right)\right] = E\left[U'\left(\tilde{W}\right)\left(B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right)\right)\right] \quad (1)$$

From the definition of citizens' welfare, we know that:

$$\bar{W} = EB\left(Q,\tilde{\theta}\right) - pQ \text{ and } \tilde{W} = \bar{W} + B\left(Q,\tilde{\theta}\right) - EB\left(Q,\tilde{\theta}\right)$$

When $B\left(Q,\tilde{\theta}\right) - EB\left(Q,\tilde{\theta}\right) > 0$, we have $\tilde{W} > \bar{W}$ and since $U'' < 0$:

$$U'\left(\tilde{W}\right) < U'\left(\bar{W}\right) \tag{2}$$

Therefore, we can show that the following inequality always holds:

$$U'\left(\tilde{W}\right)\left[B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right)\right] > U'\left(\bar{W}\right)\left[B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right)\right] \tag{3}$$

This inequality always holds because when $B\left(Q,\tilde{\theta}\right) - EB\left(Q,\tilde{\theta}\right) > 0$, we have $B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right) < 0$ since $B''(Q) < 0$. When $B\left(Q,\tilde{\theta}\right) - EB\left(Q,\tilde{\theta}\right) < 0$, the inequality sign in (2) is reversed but then multiplication by $B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right) > 0$ will still make the inequality sign of (3) hold. Taking expectations on both sides of (3), we get:

$$E\left[U'\left(\tilde{W}\right)\left(B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right)\right)\right] > E\left[U'\left(\bar{W}\right)\left(B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right)\right)\right]$$

As $U'\left(\bar{W}\right)E\left[B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right)\right] = 0$, it becomes:

$$E\left[U'\left(\tilde{W}\right)\left(B'\left(Q,\tilde{\theta}\right) - EB'\left(Q,\tilde{\theta}\right)\right)\right] > 0$$

From equation (1), we deduce that:

$$E\left[U'\left(\tilde{W}\right)\left(p - EB'\left(Q,\tilde{\theta}\right)\right)\right] > 0$$

And since $U'\left(\tilde{W}\right) > 0$, we finally find:

$$p > EB'\left(Q,\tilde{\theta}\right)$$

When marginal benefits are stochastic, the first-order condition implies that risk averse citizens will not operate as under risk neutrality, where the permits price equals its expected marginal benefit, but where the permits price exceeds the expected marginal benefit. This means that when pollution victims exhibit risk aversion, they consume more emissions reductions than under risk neutrality. In other words, citizens purchase and retire more permits under risk aversion than under risk neutrality.

If we return to our set of diagrams presented above, risk aversion implies a shift to the right of the citizens' expected marginal benefit curve. To illustrate this behavioural relationship and in order to avoid adding another curve to these diagrams, we now suppose that MB_C depicts citizens' behaviour under uncertainty and risk aversion. For example, if we assume that citizens rely largely on the regulator's expectation (MB_E), citizens' risk aversion about the benevolent nature of the regulator or about the severity of the environmental and economic effects of pollution will lead citizens to retire an amount of permits defined as $Q_C - Q_E$. In figure 1, if we assume that citizens' expectation is correct (MB_R), the effects of risk aversion will lead citizens to retire permits beyond the optimal pollution level: $Q_C - Q_E$ permits and not $Q^* - Q_E$ permits as under risk neutrality. Thus, we see that depending on the significance of the citizens' expectation error and on the degree of citizens' risk aversion, the curve MB_C can sit below or above the optimal pollution level. Hence, it appears that the citizens' expectation error can be aggravated or ameliorated by the effect of risk aversion. Therefore, we can conclude that, under uncertainty and risk aversion, citizen participation in pollution permits market can increase or decrease welfare level.

We can now add to the "prices versus quantities" debate by considering a situation in which both citizens and firms are risk averse. In this theoretical setting, it appears that the regulator cannot limit the effects of firms' risk aversion in the case of an emission tax (Adar and Griffin 1976); whereas he can control the negative effects of citizens' risk aversion by totally or partially restricting the number of permits that citizens are able to purchase and retire from the market.

5 Conclusion

When the quantity set by the regulator is too lenient, Shrestha (1998) argues that a pollution permits market where pollution victims can buy and retire permits from the market will prove superior to both standards and emissions tax regardless of the benefit or cost uncertainty. In agreement with this paper, subsequent literature extols the theoretical merits of citizen participation in pollution permits market. In short, citizen participation in emissions trading should always be considered because when non-polluting agents purchase and withhold emission rights, this means that the overall quota is not efficient and therefore welfare gains will be realised.

In this paper, we reconsider this policy recommendation, first, by relaxing Shrestha's assumption of well-informed citizens about the future benefits of pollution control; and second, by introducing risk aversion into the analysis. Thus, we argue that citizen participation in pollution permits market should be implemented cautiously. Indeed, when non-polluting players purchase and withhold permits, this is not necessarily welfare-increasing.

Previous literature supposes that influences which lead to the purchase and withholding of too few permits (free riding, the problem of the commons and the existence of transaction costs) will prevail over the influence which leads to withholding too many permits (impurely altruistic behaviours). In this paper, we identify two other influences which can lead to pollution victims buying and retiring too many permits: benefit uncertainty and risk aversion on the citizens' side. Given all these competing influences, it is difficult to anticipate which will prevail over. Intuitively, we can think that the first three influences, especially free riding, are likely to prevail over the other three influences. But there is no reason to assume that this will be the case for all environmental problems. In theory, the range of situations in which citizen participation can increase the initial welfare loss is very wide. Allowing citizens to retire as many permits as they wish can therefore be risky. As citizen participation has certain merits (revelation of preferences); it seems preferable not to prohibit pollution victims from buying and retiring permits but to put certain limits on the number of permits which may be retired. More precisely, we propose that the regulator limit citizens' action to a certain number of permits, in order to maintain the possibility of getting closer to the optimal level of pollution without risking high welfare loss. In addition, it seems important that the regulator should help potential purchasers by providing more information.

Our results can therefore be summarised by the following points:

1. Citizen participation in pollution permits market should always be implemented without restrictions on the number of permits which can be retired when pollution victims know with certainty the marginal benefit of pollution control.
2. Citizen participation in pollution permits market should be allowed with some restrictions on the number of permits which can be retired
   (a) when citizens are also under uncertainty about the marginal benefit of pollution control;
   (b) when citizens exhibit risk aversion.
3. A pollution permits market is superior to an emission tax when firms and citizens exhibit risk aversion because:
   (a) with an emission tax, the regulator cannot control the negative effects of firms' risk aversion on welfare;
   (b) with a marketable permits system, the regulator can control the negative effects of citizens' risk aversion on welfare by preventing or limiting citizen participation in the trading process.

To determine (under uncertainty) the maximum number of permits that citizens can purchase and retire, the regulator may for instance use as a basis the more stringent scientific scenario. It is worth observing that the setting of this limit will inevitably play a part in the lobbying game. We believe that this latter point could be an interesting topic for future research in which the repetitive nature of tradable permits markets could be addressed. Indeed, for environmental groups, buying and retiring permits reinforce their credibility when undertaking a lobbying action to ask institutions for (in addition to the emission reduction percentage which is already expected for the following exchange period) an overall quota reduction equal to the number of quotas retired by citizens during the previous period.

Our current research project is to carry out an empirical study designed to assess the behaviour of citizens in the European Union Emissions Trading Scheme. As citizens are not proactively participating in the trading process mainly because they are unaware of this opportunity and because of high transaction costs, this empirical study relates more to their future behaviour. Our objectives are summarized by the following questions: Do citizens think that the optimal level of pollution has been set by the regulator? If not, what do they believe the optimal level of pollution to be? Do they think that the significance of their individual actions will be too limited in relation to the problem in question (issue of the commons)? Will they choose to free ride? If they think that they will buy and retire permits, what is their real motivation: do they derive benefit solely from emissions abatement or do they also obtain personal marginal benefits such as "warm-glow" (impurely altruistic behaviour)? And finally, what would be their choice under benefit uncertainty: to choose the status quo or over-abatement?

Figures

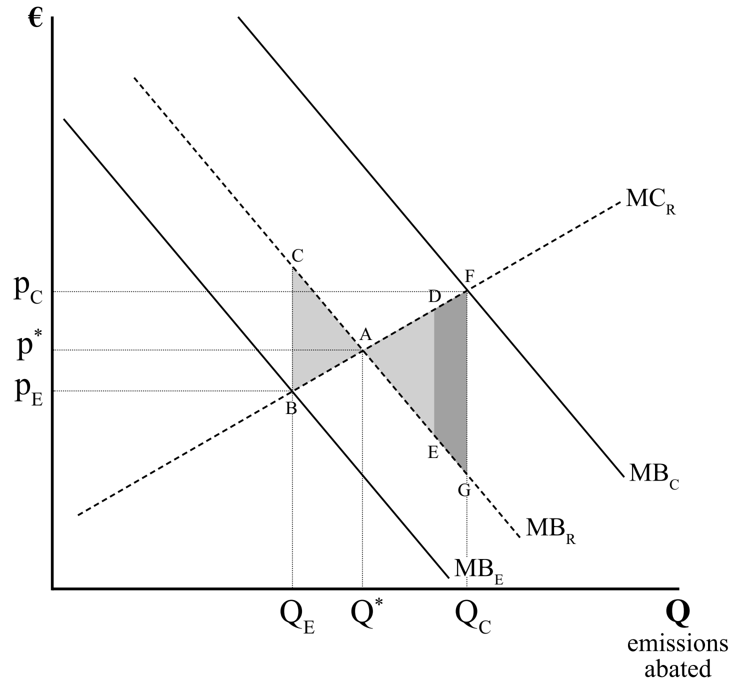

Figure 1: Choice of policy instrument under benefit uncertainty

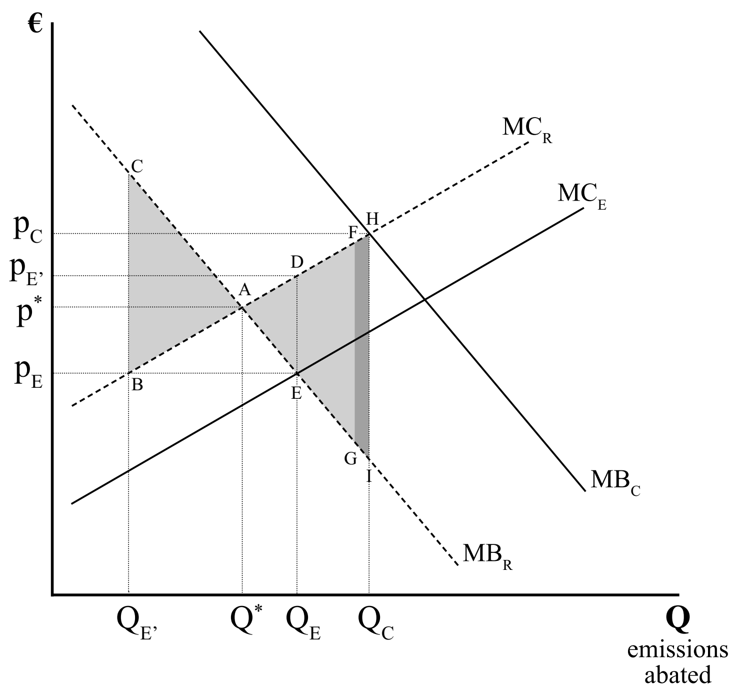

Figure 2: Choice of policy instrument under cost uncertainty

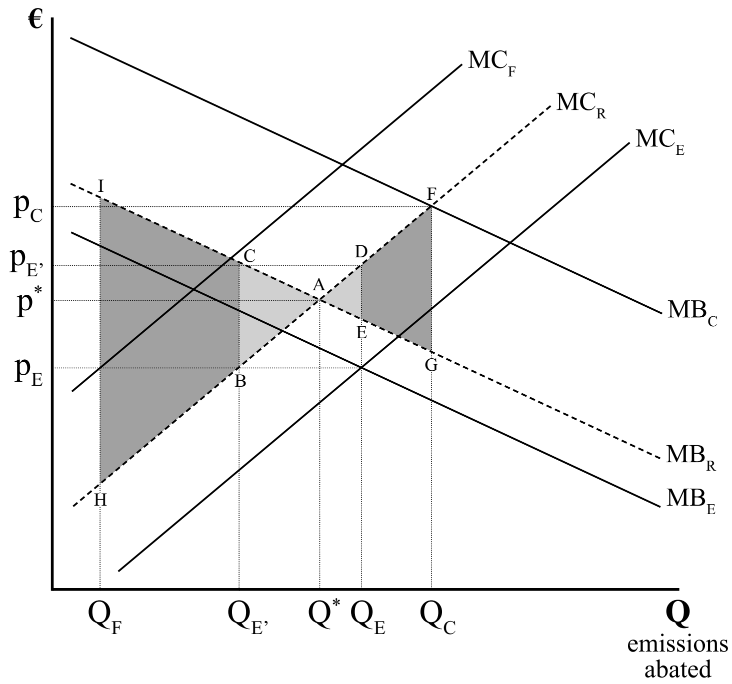

Figure 3: Choice of policy instrument under simultaneous uncertainty

Notes

[1]The "prices versus quantities" debate focuses solely on efficiency, assuming cost effectiveness for all pollution control approaches. For the sake of simplicity, we are only referring to tradable permits in the rest of this paper when we speak about quantity-based environmental regulation. For an overview of the economics of emissions trading, see Tietenberg (2006).

[2]In order to improve the readability of this paper, the expression "marginal cost" will refer to the marginal pollution abatement cost, and the expression "marginal benefit" will refer to the marginal benefit of pollution control.

[3]See Michaelowa and Butzengeiger (2005) for a general presentation of the European Union CO_2 Emissions Trading Scheme.

[4]See Israel (2007) for a survey of American experiences on this topic and a complete analysis of citizen participation in the U.S. Sulfur Allowance Auctions.

[5]The aim of carbon offset programs is to gather a certain capital in the form of donations and to develop emission reduction projects. Citizens participation in emissions trading differs from carbon offsetting in that carbon offsetting provides avoided pollution rather than actual abated pollution. The avoided pollution notion refers to the project additionality issue as well as the organization in charge of additionality verification. See Rousse (2008) for a further discussion on this topic.

[6]Weitzman (1974) assumes that the random error characterising uncertainty is sufficiently small to justify quadratic approximations of total cost and total benefit functions, i.e. linear approximations of marginal cost and marginal benefit functions.

[7]We will see later in this paper that benefit uncertainty also plays a role in choice of optimal instrument when citizens can purchase and withhold permits from the market in order to attain a lower global pollution quota.

[8]For the sake of simplicity, we assume that permits are either auctioned in the competitive market or grandfathered to polluting sources. We overlook the scenario in which environmental groups obtain the entire initial allocation because of the real danger of monopolistic or oligopolistic behaviours. Notice that the proposition of Ahlmein and Schneider (2002) to allocate permits free of charge to pollution victims (each citizen receives an initial allocation) postpones the problem. Indeed, certain pollution victims are likely to purchase and retire permits from the market if their initial allocation does not match the damage they suffer. Moreover, in accordance with the works of Kahneman et al. (1990) on endowment effect, citizens may demand firms a higher price for the trade in permits to take place, which results to a sub-optimal outcome.

[9]Dales (1968) admits that speculation in emissions trading has certain benefits.

[10]To overcome this problem, Rousse (2008) proposes that the regulator or a foundation organise citizen participation in pollution permits markets on a large scale in order to facilitate the citizens' entry into the trading process. This type of system firstly involves gathering purchase demands for a small amount of emission permits, then trading by bilateral agreement or on an exchange, and finally withholding these permits from the market. In the case of climate change, we can envisage a website through which citizens could purchase and cancel CO_2 emission permits or other purchasing solutions such as CO_2 reduction tickets which would be available in post offices or newsagents.

[11] In the case of climate change, see Dessai and Hulme (2004) for a literature review.

[12] By traffic congestion, we are only considering in this instance time spent by traffic and not the underlying problem of urban pollution from cars, whose damage is hard to determine.

[13] For the sake of simplicity, we assume in this analysis that the regulator is risk neutral; however, regulator and citizens can clearly both be risk averse.

[14] The costs characteristics are only provided for illustrative purpose of the prices vs. quantities framework and further graphical representations.

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