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VOLUNTARY AGREEMENTS AS INFORMATION SHARING DEVICES: COMPETITION AND WELFARE EFFECTS

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Voluntary Agreements as Information Sharing Devices: Competition and Welfare Effects

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Abstract

In this paper we consider Voluntary Agreements (VAs) as an information sharing device. In a duopoly model firms compete à la Cournot and aim to reduce environmental damages because consumers have green preferences that partially internalise negative externalities. However both firms are uncertain about the real cost of pollution abatement. We suppose that this kind of uncertainty is completely eliminated if firms subscribe to a Voluntary Agreement and share information. We then represent the decision process as a two stage game where firms first choose to subscribe or not to a Voluntary Agreement and then compete in quantities. Information production and disclosure about costs eliminates production errors as both firm will be able to exactly counter-adjust their output to the output produced by their opponent. Thus profits are always maximised by subscribing to Voluntary Agreements. Concerning social welfare the picture is more complicated because there can be a trade-off between the advantage of voluntary agreements from the point of view of their impact on environmental damages and their social cost in terms of higher prices and lower quantities. Actually, output counter-adjustments are "collusive" and they benefit consumers only to the extent that their direction is such to reduce output and then environmental damages. Thus consumer surplus can increase if the weight of output counter-adjustments is low with respect to output adjustment that are operated by both firms in the same direction. If the weight of output counter-adjustments is higher consumer surplus can increase only if the efficiency of pollution reducing activities inside firms differs a lot between these same firms. Our results seem to support the view that the great flexibility that voluntary agreements allow to firms with respect to mandatory standards can produce advantages also from the point of view of society.

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1. Introduction

Even if the anticompetitive effect of VAs has been an issue that has captured the attention of environmental agencies, antitrust authorities (European Commission, 1997) and social scientists, the fact that this effect may arise from information sharing practices has never been considered.

The information sharing function of VAs has already been the object of social policy analysis. Aggeri (1998) illustrates the evolution in environmental policy approach that has made information sharing a central issue for consumers, firms and the Public Administration when they share uncertainties about environmental issues. In the past environmental policy was more a "question of combating acute, localised and identifiable pollution that could be evaluated"[1]. Oil slicks, dioxins, asbestos and toxic smoke are examples of this kind of enviornmental problems. At present, issues such as the greenhouse effect, the hole in the ozone layer, cross border water pollution and waste processing define the environmental policy agenda. This type of issues are characterised by uncertainty and controversy over the identity of polluters, the validity of scientific knowledge and therefore the technological solutions that should be implemented. New techonologies are frequently called upon to face these problems and neither the industry nor the public administration precisely knows the costs and net social benefits associated to their use[2].In this framework all social actors are interested in producing and sharing information in order to improve collective learning.

In the meantime one wonders about the impact of information sharing on the competition process. If firms are uncertain not only about their own cost of pollution abatement but also about the cost of their competitors, a VA signed by a trade association may be helpful to improve information about abatement costs. Provided that firms compete in an oligopolistic setting, they will adjust their output and in turn this can affect both the distribution of output between firms and market prices. There is some evidence in the antitrust practice that trade associations may be an implicit device to restrain competition through information sharing activities. A strand of literaure devoted to information sharing in oligopoly has also widely discussed this issue, in order to ascertain the impact of information sharing either about market demand or firm costs on expected profits and, in some cases, also on expected consumer surplus and social welfare[3]. The question is that, even excluding explicit collusion by firms, VAs may have some indirect effect on the final oligopolistic equilibrium through the process of information sharing about pollution abatement costs. This process is probably particularly relevant in the case of shared uncertainties about the

[1] Cfr. Aggeri, 1998, p. 5

[2] An example could be waste valorisation, a field which has seen a great diffusion of VAs. Aggeri (1998)suggests again that while at the beginning of the nineties there was a general agreement on the fact that dumping had to be reduced, there was also a debate on waste valorisation concerning methods and targets: is it better to promote recycling or incineration with energy recovery?Was it advisable to set different targets for different materials?

[3] We can consider Ponssard (1979) as the seminal paper in this strand of literature. Ponssard deals with common uncertainty and the incentives for information sharing about a parameter measuring the vertical intercept of market demand as do the subsequent papers of Novshek and Sonnenschein (1982), Clarke (1983), Vives (1984) and Kirby (1988). Parallel works of Fried (1984), Gal Or (1986) and Shapiro (1986) deal instead with information sharing about firms'cost,i.e. private value uncertainty.

implementation of new technologies that Aggeri describes. A trade-off can arise between the increasing benefits of pollution reduction due to adjustments in output and the social costs of output restrictions to the extent that they cause a reduction in consumer surplus. Then an evaluation of social welfare and consumer surplus with and without a VA in place may be helpful from the point of view of social policy, in order to ascertain if an exemption clause may be granted by antitrust authorities to VAs that are supsected to give rise to anticompetitive practices (European Commission, op.cit.).

In this paper we then consider a duopoly model, inspired to Fried (1984) where firms compete à la Cournot and aim to reduce environmental damages caused by their production activities, because consumers have green preferences as in Garvie (1997). However green technologies are stochastic, as both firms are uncertain about the real cost of pollution abatement.We suppose that this kind of uncertainty is completely eliminated if firms negotiate a VA and share information.

The decision process is then represented as a two stage game where firms firstly choose to subscribe or not to Voluntary Agreements and then choose the quantity of output to supply. Information production (knowing precisely firm's own costs) and disclosure (revealing its cost to the opponent) about pollution abatement costs eliminates production errors and modifies the distribution of output among firms. In particular, each firm will then be able to exactly counter-adjust its output to the output produced by its opponent. As we shall see the result is that profits are maximised by negotiating a VA.

Concerning social welfare, there can be a trade-off between the advantage of VAs from the point of view of their impact on environmental damages and their social cost in terms of higher prices and lower quantities. While the results already achieved in the literature point out that even if social welfare is enhanced by information sharing, consumers surplus always decreases because consumers can profit from production mistakes (Shapiro, 1986), introducing environmental damages as we do can changes the picture. Actually, output counter-adjustments are "collusive" and they benefit consumers only to the extent that they reduce output environmental damages. Thus consumer surplus can increase if the weight of output counter-adjustments is low with respect to output adjustment that are operated by both firms in the same direction (high correlation between firms'costs). If the weight of output counter-adjustments is higher, consumer surplus can increase only if the efficiency of pollution reducing activities inside firms differs a lot between these same firms.The intuition for this last result is probably connected to the fact that even if a large increase of output by one firm follows the decision to counter-adjust the decrease of output by the opponent (whose costs are supposed to be higher), its impact on environmental damages can be low if this firm is also the most efficient from the point of view of pollution abatment.

The model is presented in section two. Equilibrium analysis follows in section three, while section four is devoted to social welfare analysis. Some conclusions follows in section five.

2. The Model

We consider a market for an homogeneous good produced by two firms: firm i and firm j, that compete à la Cournot. The willingness to pay of consumers for any quantity of that good negatively depends on the environmental damage caused by production activities, so that externalities can be internalised as in Garvie (1997). Thus we suppose that market demand is linear and represented by the following expression:

$$P = a - b(q_i + q_j) - \theta D$$

being $D = D_i + D_j$ the total net environmental damage caused by this industry and θ $(0 < \theta < 1)$ a parameter measuring the extent of internalisation of environmental externalities by consumers. The assumption that consumers only partially internalise the negative externality seems to be quite reasonable for many reasons. One can invoke the "intensity" of green preferences and/or account for the fact that consumers are generally less informed than firms with respect to the amount of environmental damages caused by production. However in this model we do not concentrate on this issue[4].

We shall distinguish between gross and net environmental damage. Any firm is characterised by the following net environmental damage function:

$$D_i = \delta q_i - \gamma_i E_i$$

where δ $(\delta > 0)$is a parameter - equal across firms -measuring the degree of toxicity of the inputs used in production, E_i is the level of the emission control input, and γ_i parametrizes the efficiency of pollution abatement activities. As $\gamma_i < 1$ the pollution production function is such that a unit of production increases pollution by δ units while installation of a unit of emission control input reduces pollution by less than one unit. Further we assume that $E_i = \delta q_i$: thus any firm should reduce pollution to a level equal to the gross environmental damage caused by production. A net environmental damage remains anyhow because of the efficiency parameter[5]. On the basis of these assumptions we can then write the environmental net damage function as:

$$D_i = \delta(1 - \gamma_i) q_i$$

We can assume that both θ and δ are equal across firms. Thus the only asymmetry between them concerns their efficiency in dealing with pollution abatement activities parametrized by γ. We suppose that this kind of efficiency is firm specific and not linked to the technology adopted but to management and organisational skills that can be firm specific. One way to think about it is to consider the adoption of environmental management systems inside firms recognized by environmental certification, either private or public.[6]. Letting then $[b + \theta\delta(1 - \gamma_i)] = \beta_i$ and $\left[b + \theta\delta(1 - \gamma_j)\right] = \beta_j$ the market demand function becomes:

$$P = a - \beta_i q_i - \beta_j q_j$$

As to technology, we suppose that any firm is characterized by constant returns to scale

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[4] This problem is related to the credibility of environmental policies put in place by firm. Firms may be able to build an environmental reputation to supplement the asymmetry of information with respect to consumers as it is shown in Cavaliere (1999).

[5] Of course one should assume that it is phisically impossible to eliminate all waste.

[6] The ISO 14000 and EMAS certification are examples of the recognized improvement in environmental management inside firms.

both in output production and pollution abatement. Further, we suppose that production costs are normalized to zero in order to concentrate just on pollution abatement costs that are represented by the following expression

$$C(E_i) = w_i \delta q_i$$

being w_i the unitary cost of pollution abatement for firm i. Now, considering $C_i = a - w_i \delta$, the profit funtcion of firm i becomes

$$\Pi_i = C_i qi - \beta_i q_i^2 - \beta_j q_j q_i$$

However we assume that firms are uncertain about the exact value of pollution abatement costs, because environmental technologies are frequently stochastic, especially when they incorporate recent innovations. Uncertainty for both firms concerns the parameters C_i and C_j. Following Fried (op.cit) we assume that these parameters are random variables having a joint normal distribution with means $\overline{C_i}$ and $\overline{C_j}$, variances $V_i^2$and $V_j^2$and covariances $V_{ij} = rV_iV_j$ (where r is the correlation coefficient).

In each period nature chooses the values of C_i and C_j, before firms choose output. Strategic interaction between firms can be represented by a two stage game. In the first stage firms can choose to negotiate or not a VA. Negotiating a VA firms produce and disclose information about pollution abatement technologies, and thus the precise values of C_i and C_j chosen by nature become common knowledge. If firms do not negotiate a VA, they remain uncertain about these parameters, just knowing their mean values: $\overline{C_i}$ and $\overline{C_j}$. In the second stage of the game firms choose output on the basis of their information about C_i and C_j, resulting from their commitments in the first stage

3. Equilibrium Analysis

Solving the two stage game by backward induction one can show the following proposition

Proposition 1 *In the framework of Cournot competition with shared uncertainties about environmental technologies, duopolist maximise profits by negotiating a VA and sharing information about environmental costs.*

Proof: Starting from the second stage of the game each duopolist on the basis of his own information will maximise expected profits. Thus we firstly distinguish the information sets resulting from the committment of the first stage. Let $I_i = I_j = \overline{(\overline{C_i}\,;\overline{C_j})}$ the information set of firm i and firm j when they do not enter into a VA and $I_i = I_j = (C_i;\, C_j)$ the information set of firm i and firm j when they enter into a VA. Then both firms will choose their output simultaneously and non cooperatively by solving the following maximisation problem in q_i:

$$MaxE(\Pi_i \mid I_i) = E\left[((C_i - \beta_i q_i - \beta_j q_j) \mid I_i) q_i\right] \tag{1}$$

The first order condition is:

$$E\left[(C_i - \beta_j q_j) \mid I_i\right] - 2\beta_i q_i = 0 \tag{2}$$

Clearly equilibrium depends on the information set. We then distinguish case A in which $I_i = I_j = (\overline{C_i}\,;\overline{C_j})$ and case B, in which $I_i = I_j = (C_i\,, C_j)$. In case A the duopolists reaction functions are the following:

$$q_{iA} = \frac{\overline{C_i} - \beta_j q_j}{2\beta_i} \tag{3}$$

$$q_{jA} = \frac{\overline{C_j} - \beta_i q_i}{2\beta_j} \tag{4}$$

and the corresponding equilibrium outputs are then:

$$q^*_{iA} = \frac{2\overline{C_i} - \overline{C_j}}{3\beta_i} \tag{5}$$

$$q^*_{jA} = \frac{2\overline{C_j} - \overline{C_i}}{3\beta_j} \tag{6}$$

Concerning case B, one can just substitute the precise values of C_i and C_j chosen by nature to the mean values $\overline{C_i}$, $\overline{C_j}$. Further, letting $\Delta C_i = C_i - \overline{C_i}$ and $\Delta C_j = C_j - \overline{C_j}$ it is possible to represent equilibrium output quantities in case B as an "excess" output with respect to equilibrium output quantities in case A:

$$q^*_{iB} = q^*_{iA} + \frac{2\Delta C_i - \Delta C_j}{3\beta_i} \tag{7}$$

$$q^*_{jB} = q^*_{jA} + \frac{2\Delta C_j - \Delta C_i}{3\beta_j} \tag{8}$$

In order to show that firms will commit to information production and disclosure by entering a VA in the first stage of the game, we have to verify that in equilibrium expected profits in case B are higher with respect to expected profits in case A. Using (1) and (2) and just considering firm i, one can check that:

$$\Pi^*_{iA} = \beta_i (q^*_{iA})^2 \tag{9}$$

$$\Pi^*_{iB} = \beta_i (q^*_{iB})^2 = \beta_i (q^*_{iA} + \frac{2\Delta C_i - \Delta C_j}{3\beta_i})^2 \tag{10}$$

Further, using the expected value operator one obtains:

$$E(\Pi^*_{iB}) = E(\Pi^*_{iA}) + \frac{4V_i^2 - 4rV_iV_j + V_j^2}{9\beta_i} \tag{11}$$

Then $E(\Pi^*_{iB}) \geq E(\Pi^*_{iA})$ if and only if: $\frac{4V_i^2 - 4rV_iV_j + V_j^2}{9\beta_i} \geq 0$. We can rearrange this last condition to get the following:

$$\frac{(1-r^2)}{9\beta_i} V_j^2 + \frac{\left[2 - r\left(\frac{V_j}{V_i}\right)\right]^2}{9\beta_i} V_i^2 \geq 0 \tag{12}$$

It is easy to check that, given the assumptions of the model about β, this condition is always verified.

Lemma 2 *The private benefit of information sharing for firm i increases with* V_i^2, V_j^2 *and* γ_i *and decreases with* r, b, δ *and* ϑ.

With the demonstration of proposition one we have shown that firms have an incentive to enter a VA in order to share information about the cost of pollution abatement. The advantage for each duopolist is to eliminate production errors due to uncertainty not only about his own cost but also about the cost of his opponent, that prevent firms to reach the Cournot equilibrium. As it is stated in lemma 2, condition (12) shows that the advantage of information sharing is increasing with the values of V_i^2 and V_j^2, representing the degree of ex-ante uncertainty about pollution abatement costs that is solved ex-post via the VA. Further the same condition makes also clear that the advantage of information sharing is increasing with the degree of divergence between $V_i$and V_j,affecting the covariance between firms.The private benefits of information sharing also decrease when the correlation coefficient increases. Again the covariance is affected. In fact the secon term in (11) shows clearly that when the covariance increases the benefis of information sharing decreases. Thus the benefits of information sharing are even greater when uncertainty particularly concerns the cost of one firm with respect to the other one and when costs and output adjustments go in oopposite directions. In fact any firm, disclosing information to his opponent, enable him to accomplish the necessary counter-adjustments that are necessary to attain the Cournot equilibrium.The extent of output adjustments and counteradjustments is directly observable in the model through the "excess" equilibrium output quantities that are produced by firms when a VA is in place, with respect to when it is not, as shown in (7) and (8).Thus concerning firm i we have:$\Delta q_i = \frac{2\Delta C_i - \Delta C_j}{3\beta_i}$ and concerning firm j:$\Delta q_j = \frac{2\Delta C_j - \Delta C_i}{3\beta_j}$. As these expression well illustrate we can distinguish for each firm a "direct" output adjustment given by $\frac{2\Delta C_i}{3\beta_i}$ for firm i and by$\frac{2\Delta C_j}{3\beta_j}$ for firm j and a counter-adjustment to the output produced by the other firm, represented respectively by $-\frac{\Delta C_j}{3\beta_i}$ and by $-\frac{\Delta C_i}{3\beta_j}$. As Fried (op.cit.) points out, parallel to the previous distinction, the information disclosed can also be implicitly decomposed into two: components: 1)"Firm specific" cost information, yielding for example to firm i some additional knowledge about firm j's costs, but no additional knowledge about firm i own costs 2)"Common" cost information (concerning industry for example), yielding to firm i some additional knowledge about his own costs, through the disclosure of cost information about firm j. Firm specific cost information enables each firm to make the necessary counter-adjustments to the revision of output carried out by its opponent on the basis of information sharing. These counter-adjustments are "collusive", to the extent that they materialize in output decisions that are necessary to achieve non-cooperatively the Cournot equilibrium. Actually, it is easy to verify that, for each duopolist, counter-adjustments to the cost function of the opponent are in the opposite direction with respect to the direct adjustment made by the opponent himself. Any change of output by any firm in any direction is more beneficial when accompanied by a change made in the opposite direction by the other firm, given the final effect on market price. If firms'costs are to some extent positively correlated, information production and disclosure will give rise to a revision of expected cost and to output variations that go in the same direction for both firms. These revisions will not be "collusive" and as such will reduce the beneficial impact of output counter-adjustments. Of course this last effect is expected to be more pronounced the higher is r, the correlation coefficient, measuring the degree of correlation between firms'costs.

Further, both "direct" output adjustments and counter-adjsutments depend on β. Environmental parameters play then a role in determining the extent of these adjustments. We can assume that b, δ and θ are industry and market parameters that affect firms in the same way. The positive effect of information sharing on profits decreases when the value of such parameters increases. The efficiency of pollution abatment γ, may differ instead between producers. As stated in lemma 2 the private incentives for firm i to share information increase with γ_i, as results from (12) and the expression of β. The extent of output adjustments and counteradjustments will then be affected by γ because the most efficient firm will always produce more with respect to the amount of output that is needed to counter-adjust the revision of output of his opponent. The most efficient firm derives more benefits from information sharing. Even if producing a little bit more could hurt profits by reducing market price, this effect could be (at least partly) compensated because the high effciency of pollution abatement raises the willingness to pay of consumers. On the contrary the less efficient firm will always produce less with respect to the amount of output that is needed to counteradjust the revision of output by the other firm.Its profits will then increase less because of the fact that it produces less. The market price should then decrease to a lesser extent because output increases to a lesser extent and also because the firm that produces less is also the less efficient from the environmental point of view. The final effect on equilibrium prices will depend both on the total amount of output that firms non-cooperatively will put on the market and on the net environmental damage that finally results, given its effect on consumers' willingness to pay.

4. Information Sharing and Social Welfare

Last section clearly established that in the framework of shared uncertainties VAs increase profits thanks to information sharing about costs. In the final market equilibrium not only prices and output quanities are changed by information sharing, but also the net environmental damage varies. One wonders then about the social welfare effects of information sharing, as output contractions due to non cooperative behaviour may be coupled with reductions of environmental damages. On the contrary output expansions can be coupled with an increase of environmental damages. Assessing the impact of social welfare may then provide criteria for public policy decisions concerning VAs.

We then assume the existence of a social planner whose objective is to maximise social welfare. The social planner will take care of the residual production externality: the part of environmental damages not internalised by the market.The social welfare function is then given by the sum of producer and consumer surplus minus the residual environmental damages:

$$W = \int_0^q (a - \beta_i q_i - \beta_j q_j)dq - \delta w_i q_i - \delta w_j q_j - (1-\theta)(D_i + D_j) \qquad (13)$$

In order to see if public policy should foster VAs or not one must compare social welfare in the case of shared uncertainties about pollution abatement costs (case A of last section) with social welfare when a VA is in place and firms share information about environmental technologies (case B in last section). Social welfare not necessarily increases with information sharing VAs, even if profits are always enhanced by them. This may be due to a reduction of consumer surplus that overcomes the increase of profits. However it may also be possible that even in the event of an increase in social welfare, consumer surplus as such decreases. In this last case the extent of the profit increase is such to compensate the decrease in consumer surplus. It is then interesting to analyse the direct impact of information sharing VAs first on consumer surplus and then on aggregate social welfare. This analysis is shown in the following proposition

Proposition 3 *Information sharing VAs induce a decrease of consumer surplus if the covariance is negative. If the covariance is positive consumer surplus can increase only if the following inequality holds:* $\frac{r(\beta_i+\beta_j)-\sqrt{r^2\beta_i^2+(2r^2-1)\beta_i\beta_j+r^2\beta_j^2}}{\beta_i} \leq V_i/V_j \leq$ $\leq \frac{r(\beta_i+\beta_j)+\sqrt{r^2\beta_i^2+(2r^2-1)\beta_i\beta_j+r^2\beta_j^2}}{\beta_i}$*. In the latter case if* $r \geq 1/2$ *the increase of consumer surplus is independent from* $\frac{\beta_i}{\beta_j}$ *(provided that* $\beta_i \neq \beta_j$ *if* $r = 1/2$*); while if* $r \leq 1/2$ *the increase of consumer surplus depends on* $\frac{\beta_i}{\beta_j}$ *and takes place either if* $\frac{\beta_i}{\beta_j} \geq \frac{(1-2r^2)+\sqrt{1-4r^2}}{2r^2}$ *or if* $\frac{\beta_i}{\beta_j} \leq \frac{(1-2r^2)-\sqrt{1-4r^2}}{2r^2}$.

Proof: By substracting profits from the expression of social welfare we get the following expression for consumer surplus:

$$CS = \frac{\beta_i}{2}q_i^2 + \frac{\beta_j}{2}q_j^2 + (\beta_i + \beta_j)q_i qj - (1-\theta)\left[D_i + D_j\right] \qquad (14)$$

In order to compare consumers surplus in case A and case B one has to substitute in last expression the equilibrium output quantities to get $CS(q_{iA}^*, q_{jA}^*)$ and $CS(q_{iB}^*, q_{jB}^*)$ respectively. After computing expected values, in order to see if consumer surplus is positively affected by information sharing VAs, one has to control if the following inequality comes true:

$$E[W(q_{iB}^*, q_{jB}^*)] > E[W(q_{iA}^*, q_{jA}^*)] \qquad (15)$$

and this occurs if:

$$2rV_iV_j(\beta_i + \beta_j) - \beta_i V_i^2 - \beta_j V_j^2 \geq 0 \qquad (16)$$

.

It is easy to check that when $r < 0$ last inequality never comes true. When $r > 0$, rearranging (16) one can further analyse the roots of the following inequality:

$$\beta_i \left(\frac{V_i}{V_j}\right)^2 - 2r(\beta_i + \beta_j)\left(\frac{V_i}{V_j}\right) + \beta_j \leq 0 \qquad (17)$$

Such analysis leads to distinguish two different cases, according to the value of r:
Case 1:$r \geq \frac{1}{2}$
In this case last inequality comes true if and only if $\frac{V_i}{V_j}$, belongs to the following interval:

$$\frac{r(\beta_i+\beta_j)-\sqrt{r^2\beta_i^2+(2r^2-1)\beta_i\beta_j+r^2\beta_j^2}}{\beta_i} \leq \frac{V_i}{V_j} \leq \tag{18}$$

$$\leq \frac{r(\beta_i+\beta_j)+\sqrt{r^2\beta_i^2+(2r^2-1)\beta_i\beta_j+r^2\beta_j^2}}{\beta_i}$$

No restriction is placed on $\frac{\beta_i}{\beta_j}$ except that $\beta_i \neq \beta_j$ if $r=\frac{1}{2}$.
Case 2:$r < \frac{1}{2}$
In this second case not only the restrictions placed on $\frac{V_i}{V_j}$ continue to hold, but one can show that some restrictions must be placed also on $\frac{\beta_i}{\beta_j}$,as in the following:

$$\frac{\beta_i}{\beta_j} \geq \frac{(1-2r^2)+\sqrt{1-4r^2}}{2r^2} \tag{19}$$

$$\frac{\beta_i}{\beta_j} \leq \frac{(1-2r^2)-\sqrt{1-4r^2}}{2r^2} \tag{20}$$

We can comment on our results concerning consumer surplus. Intuition lead us to think that information sharing about pollution abatment costs can give rise to three different cases: 1) Both firms may contract output and thus reduce aggregate net environmental damage. While output contractions will negatively affect consumers surplus, the reduction of net environmental damages will have a positive effect on it. 2) Both firms may expand output and then net enviornmental damages would increase. While output expansion will positively affect consumer surplus, the increase of net environmental damages will have a negative effect on it. 3) While one firm may contract output, the other one will expand it.There will then be a "mixed" effect on consumer surplus and the final result depends on the relative magnitude both of the output expansion and of the output contraction. Of course the effect on net environmental damage depends on the fact that the net effect on output will be a contraction or an expansion.

The results established in proposition three, help us to understand the elements that make the positive effects on consumer surplus prevail on the negative effects. First of all let us point out that the increase in consumer surplus is highly dependent on the value of the covariance rV_iV_j. For high values of the covariance the "direct" output adjustment operated by each firm tends to overcome the "counter-adjustment"operated with respect to the disclosure of the cost of the other firm. As counter-adjustments are "collusive" they increase profits and reduce consumer surplus. Our results show that consumer surplus always decreases with information sharing if the covariance is negative ($r < 0$). If the covariance is positive consumer surplus is more likely to increase the higher is r.

As to the case in which there is negative correlation between firms'costs, direct output adjustments tend to follow opposite directions. However if there is higher negative correlation, output adjustments by both firms tends to compensate each other, even if the efficiency parameters γ_i and γ_j diverge.This tends to mitigate the final effects on consumer surplus. More interesting is the situation of low negative correlation, when it is likely that output reductions by one firm be followed by output increases of greater magnitude by the other firm or viceversa. In the first case total output is then likely to increase and environmental damage is negatively affected. In the second case total output is likely to decrease and environmental damage is positively affected. In both cases however, as stated in Proposition three, the negative effects on consumer surplus always prevail on the positive effects.

In case of positive correlation, consumer surplus is more likely to increase if the covariance is high. Any increase in the covariance implies that V_i and V_j do not diverge too much as proposition three clearly states. Moreover the covariance increases with the correlation coefficient. If the correlation between firms cost is higher, any information disclosed about the cost of one firm will provide useful information for the other one, in order to make direct output adjustments. This is the case in which firms just revise expected costs and no particular profit advantage results from information sharing. This effect is more intense the higher is r, the correlation coeffcient. Thus for high values of r the "collusive"effect tend to be compensated by the "direct" output adjustments that are made by firms in the same direction. For low values of r this is less likely to happen and crucially depends on the values of β_i and β_j.

For example if costs are not highly correlated, even if cost revisions are in the same direction, their extent can differ substantially. As a result the firm that revises cost to a lesser extent (firm j let us suppose), even finding that its cost are lower than expected will reduce output in order to "counter-adjust" the large increase of output of its opponent (firm i), whose cost revision is wider. In this case total output increases but such an increase is lower with respect to the case in which costs are more correlated. Then consumer surplus is negatively affected.

However as proposition three clearly states even when the correlation coefficient is lower, consumer surplus may still increase with information sharing because of the divergence between β_i and β_j. If we suppose that any other parameter composing β_i and β_j is equal between firms, then it is interesting to consider the divergence between γ_i and γ_j, the parameters measuring the efficiency of pollution abatement inside firms. Concerning last example, the reduction of output due to the firm whose counteradjustment outweighs its direct adjustment (firm j) has a positive effect on the reduction of the net environmental damage. One can notice that when the difference between γ_i and γ_j widens two kind of effects can operate: 1) If $\gamma_j > \gamma_i$, total output increases to a lesser extent because the counteradjustment due to firm j increases with γ_j and then environmental damage decreases with output; 2) In the opposite case, in which $\gamma_i > \gamma_j$ the "direct" adjustment of output made by firm i implies that its contribution to the increase of output reduces the increase of net environmental damage to the extent that firm i is the most efficient firm in pollution abatement.

Concerning social welfare we shall not give general results as we did for consumer surplus. However, following the same pattern of anlysis, in order to see if VAs improve or not social welfare one must substitute in the expression already given in (13) the equilibrium output quantities respectively obtained in case A and in case B, to get $W(q^*_{iA}, q^*_{jA})$ and

$W(q^*_{iB}, q^*_{jB})$ respectively:

$$W(q^*_{iA}, q^*_{jA}) = C_i q^*_{iA} + C_j q^*_{jA} - \frac{\beta_i}{2} q^{*2}_{iA} - \frac{\beta_j}{2} q^{*2}_{jA} - (1-\theta)\delta \left[(1-\gamma_i) q^*_{iA} + (1-\gamma_j) q^*_{jA}\right] \quad (21)$$

$$\begin{aligned} W(q^*_{iB}, q^*_{jB}) &= C_i(q^*_{iA} + \frac{2\Delta C_i - \Delta C_j}{3\beta_i}) + C_j(q^*_{jA} + \frac{2\Delta C_j - \Delta C_i}{3\beta_j}) - \\ &\quad -\frac{\beta_i}{2}(q^{*2}_{iA} + 2q^*_{iA}\frac{2\Delta C_i - \Delta C_j}{3\beta_i} + \frac{4(\Delta C_i)^2 - 4\Delta C_i \Delta C_j + (\Delta C_j)^2}{9{\beta_i}^2}) \\ &\quad -\frac{\beta_j}{2}(q^{*2}_{jA} + 2q^*_{jA}\frac{2\Delta C_j - \Delta C_i}{3\beta_j} + \frac{4(\Delta C_j)^2 - 4\Delta C_j \Delta C_i + (\Delta C_i)^2}{9{\beta_j}^2}) - \\ &\quad (1-\theta)\delta \left[(1-\gamma_i)(q^*_{iA} + \frac{2\Delta C_i - \Delta C_j}{3\beta_i}) + (1-\gamma_j)(q^*_{jA} + \frac{2\Delta C_j - \Delta C_i}{3\beta_j})\right] \end{aligned}$$

Once the expected values are computed, the proof just lies in controlling if the following condition comes true:

$$E[W(q^*_{iB}, q^*_{jB})] > E[W(q^*_{iA}, q^*_{jA})]. \quad (22)$$

One can show that this is equivalent to solve the following:

$$(8\beta_j - \beta_i)V_i^2 - 2(\beta_i + \beta_j) r V_i V_j + (8\beta_i - \beta_j)V_j^2 > 0 \quad (23)$$

As to the study of the latter inequality, we can conclude that, if $r < 0$ (the covariance is then negative) and $\frac{1}{8} < \frac{\beta_i}{\beta_j} < 8$ (i.e. both $(8\beta_j - \beta_i)$ and $(8\beta_i - \beta_j)$ are positive), (23) will always come true and social welfare will always increase with information sharing. Being $r < 0$, and recalling the results already given in proposition 3, this means that the magnitude of profits increase outweighs the magnitude of consumer surplus decrease that takes always place in this case. Outside of this case, in order to assure that social welfare increases with information sharing, some restrictions should be placed not only on the value of $\frac{\beta_i}{\beta_j}$, but also on the value of $\frac{V_i}{V_j}$. For example, one can show that if $\frac{\beta_i}{\beta_j} > 8$, whatever be r, social welfare increases with information sharing if and only if $\frac{r(\beta_i+\beta_j) - \sqrt{(r^2+8)\beta_i^2 + (2r^2-65)\beta_i\beta_j + (r^2+8)\beta_j^2}}{8\beta_j - \beta_i} \leq \frac{V_i}{V_j} \leq \frac{r(\beta_i+\beta_j) + \sqrt{(r^2+8)\beta_i^2 + (2r^2-65)\beta_i\beta_j + (r^2+8)\beta_j^2}}{8\beta_j - \beta_i}$

Further one can show that in this case - i.e. when social welfare can increase only for certain values of $\frac{V_i}{V_j}$- given r and $\frac{\beta_i}{\beta_j}$, this interval includes those values of $\frac{V_i}{V_j}$ shown in (18), allowing an increase of consumer surplus. This follows from the fact that any increase of consumer surplus is associated with a parallel increase of social welfare, as profits are always positively affected by information sharing (see proposition one). When $\frac{V_i}{V_j}$ is included in the latter inequality but is outside the values given in (18), consumer surplus starts to decrease. However profits increases more in the meantime and this allows for an improvement in social welfare. Finally when $\frac{V_i}{V_j}$ is not included in these intervals, that is V_i and V_j diverge too much, the decrease of consumer surplus outweighs the increase in profits, and social welfare is negatively affected.

5. Conclusions

The results that we have presented add to the past literature in providing explanations for the fact that firms may be willing to subscribe VAs in spite of the fact that any committment to overcompliance with respect to mandatory standards implies an increase of environmental costs that firms incur voluntarily. Not only we have supposed the existence of green preferences that drive firms to reduce the environmental impact of their activities, but moreover we have shown that any VA has an important information sharing function that affects competition in such a way to let firms'profits increase anyhow. Thus even if firms would be willing to accept an increase of their environmental costs, in order to satisfy consumers preferences, even without subscribing to a VA, they prefer to enter in such a negotiation with their competitor and the public administration especially when they face a situation of shared uncertainties with respect to environmental technologies. The examples that we have quoted in our introduction show that this situation characterises some important environmental issues that are on the policy agenda. The environmental effectiveness of new technologies or their actual cost are often uncertain not only for consumers and for public adminstration officers but also for firms that are directly involved in their use. That is why in the environmental field shared uncertainty may be as relevant as asymmetric information between firms and consumers or between firms and public authorities.

Even if information sharing about environmental technologies may be justified on these grounds, we have shown that it can also affect competition in an oligopolistic market. Imperfect knowledge about environmental costs prevent firms from the attainement of the Cournot equilibrium as firms cannot properly adjust their output level to their own cost and to the cost of their opponent. On the contrary entering a VA and sharing information gives firm this opportunity. Even excluding that firms will collude, the output adjustments that are carried out to reach a Cournot equilibrium are partly "collusive" to the extent that any firm adjusts its own production to the production that its opponent is expected to choose. Thus information sharing changes the distribution of output between firms and while profits are always enhanced by this effect consumer surplus may on the contrary suffer a contraction. However the consideration of environmental damages as well complicates any assessment of the information sharing function of VAs based on the variation of social welfare.

Even in the case in which information sharing just induces a redistribution of output between firms, without any net contraction or increase of total output, there could be a variation of total net environmental damage due to the difference of firms efficiency in pollution abatement activities. For example social welfare will be positively affected by the fact that the firm that increase its production after sharing information is also the most efficient firm in taking care of environmental externalities. However the less efficient firm benefits as well from sharing information as its profits will also increase, even if its contribution to the reduction of environmental damages and to consumer surplus is negative. One can say that this last firm free rides on the effort of the other one, but both them and society benefit from the existence of a VA to the extent that it enables firms to share information on pollution abatement costs.

When information sharing induces a net increase of total output, consumer surplus is positively affected but environmental damage increases. Again, only the high effciency of pollution abatement activities can limit the increase of environmental damages. If, on the contrary, information sharing induces a net decrease of output, consumer surplus is negatively affected but environmental damages will decrease. Actually there can be a trade-off between the environmental objectives requiring a contraction of output and the social target of expanding production to increase consumer surplus. However, in some cases, this trade-off can be mitigated by the difference of efficiency in pollution abatement activities. Even if only one firm is very efficient, while the other one shows a poor environmental performance, with a VA that allows them complete flexibility in output choices, both firms and consumers can derive net benefits from information sharing. Any mandatory standard conceived in order to force both firms to attain the average level of efficiency will have the effect of worsening social welfare.

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