The Cost Efficiency of Voluntary Agreements for Regulating Industrial Pollution : a Coasean Approach[1]

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Paper presented at the International Conference on the Economics and Law of Voluntary Approaches in Environmental Policy - Venice, 18-19 November, 1996

Technical abstract

This paper deals with the cost efficiency of target-based voluntary agreements for reducing industrial pollution. These agreements are contracts between a public body and an industrial association including the collective commitment of the industrial sector to reach a pollution abatement objective. In this respect, cost efficiency properties of these VAs is determined by the way burden sharing is carried out between individual firms at the implementation stage of the contract. To address this question, we develop a Coasean (neo-institutional) model which assess the ability of the VA' s burden sharing scheme based on inter-firm bargaining to minimise transaction costs. In a first part, we present the nature of the problem and discuss why a Coasean approach is suitable to deal with our question. In the next two parts part, the analytical framework is presented. The assessment is carried out in the last part. In comparison with economic instruments and command and control approaches, we show that VAs are cost efficient in the following context : very large shared uncertainty about pollution abatement techniques, concentrated industrial sectors in which the heterogeneity in pollution abatement activities and costs is low.

Non technical abstract

Voluntary agreements (VAs) are increasingly considered as a potentially useful environmental policy tools by practitioners. In the policy debate, it is often argued that VAs are a cost effective policy option to reach environmental targets. The goal of this paper is to investigate in what context this assumption is true. Given that VAs are very diverse, we investigate one particular type of VAs which is the most frequently encountered in the European Union : the negotiated agreement between a public authority and an industrial sector focusing on one particular industrial pollution concern and including a collective quantified pollution target to be met by the firms of the industry. We show that these target-based VAs are cost efficient in the following context : very large shared uncertainty about pollution abatement techniques, concentrated industrial sectors in which the heterogeneity in pollution abatement activities and costs is low. To demonstrate this result, we develop an original analytical framework. Our approach is Coasean since the assessment of VAs takes into account *transaction costs*. Given that VAs are negotiation-based institutional arrangements, this theoretical orientation stems from the fact that usual arguments about cost efficiency of bargaining are related to the transaction costs this mode of resource allocation entails. In a first part, we present the nature of the problem and discuss why a Coasean approach is suitable to deal with our question. In the second part, we precisely characterise this approach. The analytical framework is presented in a third part while the assessment is carried out in the last part.

Introduction

Voluntary agreements (VAs) are increasingly considered as a potentially useful environmental policy tools by practitioners. Even though VAs are very diverse, the type which is the most frequently encountered in the reality presents the following characteristics : it is a collective agreement between a public authority and an industrial sector focusing on one particular industrial pollution concern and including a collective quantified pollution target to be met by the firms of the industry. Regarding these target-based VAs, the policy debate about their efficiency focuses on three main points :

(i) Is the collective target set in the agreement socially satisfying ? More precisely, it is questioned whether business participation into target setting results in too low environmental objectives. In some cases, it has been argued that targets are even lower than what would have been reached in "Business As Usual" conditions (Kolhaas et al, 1995).
(ii) In many cases, VAs do not have any legal status. No formal sanctions are thus available in case of non compliance. It leads to enforcement concerns about these agreements which are weakened by potential free riding behaviours of individual firms.
(iii) Finally, the question of their cost-efficiency, especially in comparison with other policy options (economic instruments and direct regulation) is also under scrutiny.

This paper deals with the third question, i.e. the cost efficiency of VAs[2]. We show that VAs are cost efficient in the following context : very large shared uncertainty about pollution abatement techniques, concentrated industrial sectors in which the heterogeneity in pollution abatement activities and costs is low. To demonstrate this result, we develop an original analytical framework. Our approach is Coasean since the assessment of VAs takes into account *transaction costs*. Given that VAs are negotiation-based institutional arrangements, this theoretical orientation stems from the fact that usual arguments about cost efficiency of bargaining are related to the transaction costs this mode of resource allocation entails. In a first part, we present the nature of the problem and discuss why a Coasean approach is suitable to deal with our question. In the second part, we precisely characterise this approach. The analytical framework is presented in a third part while the assessment is carried out in the last part.

1. The problem : burden sharing, inter-firm bargaining and transaction costs

In this paper, we consider target based VAs with the following key features :

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[2] It has to be noticed that we do not take into account enforcement costs which refer to the second question. In other words, we assume that enforcement is perfect to abstract from this point.

- They are formal agreements signed by a public authority and an industrial association representing the n firms of a particular sector
- The agreements include an industrial commitment in pollution abatement. This commitment is expressed in quantitative terms and is collective (i.e., it is a global target to be met by the whole industry).
- The collective target has to be reached by a date specified in the agreement (usually in 3 to 10 years).

Possible examples are the numerous Dutch covenants issued for implementing the national environmental objectives of the NEPP (the Dutch green plan), the several Danish, French or German agreements with high energy consuming sectors to reduce CO_2 emissions.

As far as cost efficiency is concerned, the problem takes place at the implementation stage. Once the contract is signed, firms have to share between themselves the pollution abatement efforts required to reach the target. In analytical terms, the issue is to efficiently allocate private pollution abatement objectives between firms. Cost minimisation will be reached if the allocation leads to the equalisation of private marginal abatement costs. Is it possible ?

In previous contributions on this topic (Glachant, 1995), we have shown that the burden sharing process is a n-players bargaining game : (i) under the constraint provided by the collective target, it is a positive sum game given that the issue is to reduce pollution abatement costs incurred by the firms ; (ii) each firm is completely free regarding the selection of its own strategy in the game.

Since Nash (or even Edgeworth !), bargaining has been studied by many economic scholars. One general lesson of these investigations is that, in bargaining context, the total exploitation of the "gain from trade" is hindered by two combined factors. Firstly, as pointed out by Schelling (1960), there is the distributive problem. When bargaining, the players objective is twofold : (i) to generate a surplus by exploiting the potential gain from trade, (ii) to share the then-created surplus between themselves. This latter conflicting distributive dimension makes difficult, long or costly the achievement of the agreement. Secondly, to define his own strategy, each player needs to assess the preferences of the other players. Because information on preferences is usually private, it leads to strategic behaviour (i.e. manipulation of information) causing costs and delays. In the last ten years, the non cooperative bargaining theory has extensively addressed this issue (see for instance, Kennan and Wilson, 1993, for a survey on this question). Such difficulties can be sum up by a simple statement : the allocative efficiency of bargaining is threatened by high transaction costs. It follows that the assessment of VAs' cost efficiency requires in one way or another the evaluation of bargaining transaction costs.

2. The Coasean analysis of the cost efficiency of VAs

In fact, in his famous article "The Problem of Social Cost", Coase was paying attention both on transaction costs and on bargaining solutions in the analysis of environmental policies. Indeed, what was the proposals of Coase in this paper ? Firstly, as an alternative to direct public intervention, he was arguing about the usefulness of negotiated solution to solve externalities, the Coasean solution. Secondly, Coase was claiming that the comparative analysis of the efficiency of the Coasean solution versus the Pigovian

solution has to take into account transaction costs[3]. Of course, VAs are negotiated solutions which largely differ from the Coasean decentralised bargaining between polluters and polluttees. When using VAs, negotiations take place between public bodies and polluters at the formation stage of the contract and between polluters at the implementation stage. Nevertheless, the Coasean general orientation seems very suitable to deal with our question. This "Coasean" approach[4] is based on three general principles :

1. The distinction between transaction costs and production costs is crucial. It is based on the idea that production costs depend on technology and inputs whereas transaction costs depend only on the way transactions are organised. As stated by Arrow (1969), "the distinction between transaction costs and production costs is that the former can be varied by a change in the mode of resource allocation, while the latter depend only on the technology and tastes, and would be the same in all economic systems". It follows that, when assessing policies, one need only to deal with transaction costs. In other words, the question refers to the ability of a policy to minimise transaction costs.

2. To assess transaction cost, policies are considered as institutional arrangements. An institutional arrangement characterises the way the transactions are organised. Therefore, it describes the interactions and the role of the agents involved in policy making (i.e. the regulator and the regulatees). In this respect, policies are seen as collective decision schemes and the notion of institutional arrangement characterises the organisational form of these schemes.

3. The efficiency assessment has to be comparative. It means that the relative efficiency of a particular institutional arrangement has to be carried out in comparison with the other available institutional alternative options. Such a principle has been put forward by Demsetz (1969) to escape from the so-called 'Nirvana approach' developed by the Pigovians. In his view, the basic problem of welfare economics is the reference used to define externalities (or market failures in general). The externalities are deviations from a Pareto optimum defined in the ideal Walrasian world without any positive transaction costs. The Pigovian tradition advocates public intervention to fill the gap between this ideal point and the studied situation. This give birth to a constant normative willingness to reach perfection (the Nirvana). As we say in French 'le mieux est ennemi du bien' and beyond a certain level, the policy arrangements which are designed exhibit higher administrative costs than the resulting increase in welfare.

According to these principles, our goal is thus to compare the relative ability of VA 's burden sharing scheme to minimise transaction costs in comparison with other available policy options. In this paper, we will use two benchmark, namely, economic instruments and command and control approaches.

We can go further in the characterisation of our project by identifying the nature of transaction costs incurred by the firms and the regulator in burden sharing processes: *they can be considered as information collection and processing costs*[5]. Let us argue this point in the three cases.

VAs :

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[3] This latter aspect has often been neglected. As a matter of fact, the extensive discussion of this paper in the economic literature has focused on the so-called Coase theorem, a result valid in a world of zero transaction costs.

[4] It can also be labelled as "neo-institutional" in fact.

[5] One can note that it has been argued that, in fact, in every cases, transaction costs are information collection and processing costs (Dahlman, 1979).

When using VAs, burden sharing activity is located at the firm level. It consists in three tasks. First, firms collect information about their own existing pollution abatement activity and about pollution abatement cost they will incur to cope with the additional efforts the VA requires. Secondly, they have to collect the same kinds of information about the other firms in order to strengthen their bargaining position. Thirdly, they incur computation costs in order to define their bargaining strategy and to interpret other players' strategies.

In fact, there is a last step : once the allocation of individual efforts is agreed, firms implement their private objective. But it is not necessary to question this implementation phase which is common to the three policy approaches.

Command and control approaches :
In this case, burden sharing is decided by the regulator. Nevertheless, he needs information about private pollution abatement costs to make his decision. As such information is owned by the firms, burden sharing activity firstly consists in communication between the regulator and the firms about pollution abatement techniques and costs. This communication is difficult because of strategic behaviors of individual firms (information manipulation) : they have a clear incentive to report to the regulator overestimated private pollution abatement costs in order to get an individual pollution abatement effort as low as possible. Once the regulator has collected the relevant information, he computes it to select an allocation and communicates its plan to the regulatees.

Economic instruments
When using the market mechanism, the allocation of efforts is achieved via the adjustment of firms to the price signal[6] . This is a decentralised scheme : burden sharing is completely carried out by individual firms. What does it consist in ? First, firms have to get information about pollution abatement techniques, costs and the price signal. Then, they compute it to adjust their initial level of pollution abatement. Finally they implement pollution abatement.

We are now able to answer the following question: what is a Coasean analysis of the cost efficiency of VAs ? It consists in assessing the relative ability of the three burden sharing schemes to minimise information costs, or in other words, an assessment of the information efficiency of the three burden sharing schemes. One can compare this approach with the traditional (Pigovian) analysis of the cost efficiency of environmental policy instruments developed by Baumol and Oates (1988). In the latter, analytical units are instruments (taxes, emission standards). Its logic is to quantify changes in the production costs of the firms due to their adjustments to the instrument. For instance, emission standards are characterised as a set of identical private pollution abatement objectives. They are not cost efficient since identical private pollution abatement objectives do not lead to the equalisation of marginal private production cost. In comparison, our project consists in moving the focus of the analysis (i.e. in changing the analytical unit). We do not study the result of the burden sharing process (e.g. a set of identical private objectives in the case of command and control approach), but the process itself (e.g. an institutional arrangement based a centralised decision by a regulator who collect relevant information from firms).

3. Assessing the informational efficiency of VAs : the analytical framework

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[6] To simplify, we consider that the price signal is given. It is true in the case of tradable permits since the price spontaneously emerges. It is not true in the case of emission taxes, since the price results from a computation by the regulator.

Having identified the precise content of our project, we need now to undertake it ! This section presents the main building blocks we use. The analysis *per se* is carried out in the last section.

A taxonomy of informational tasks : communicating, inquiring, deciding

In the previous part, we have briefly described the different informational tasks related to burden sharing. We have seen that they are very diverse. In fact, we can simplify this picture by using the taxonomy of informational tasks in collective decision contexts designed by Marschak (1968). He considers that a decision is a process which transforms a piece of information into another piece of information. Marschak distinguishes three "transformers" : inquiring, communicating and deciding. Inquiring and communicating are two possible modes for collecting information (cf. figure 1). Inquiring consists in the direct observations of the phenomena about which you need information. Communication is to get information from other agents who are better informed. Deciding is related to information processing (i.e., computation).
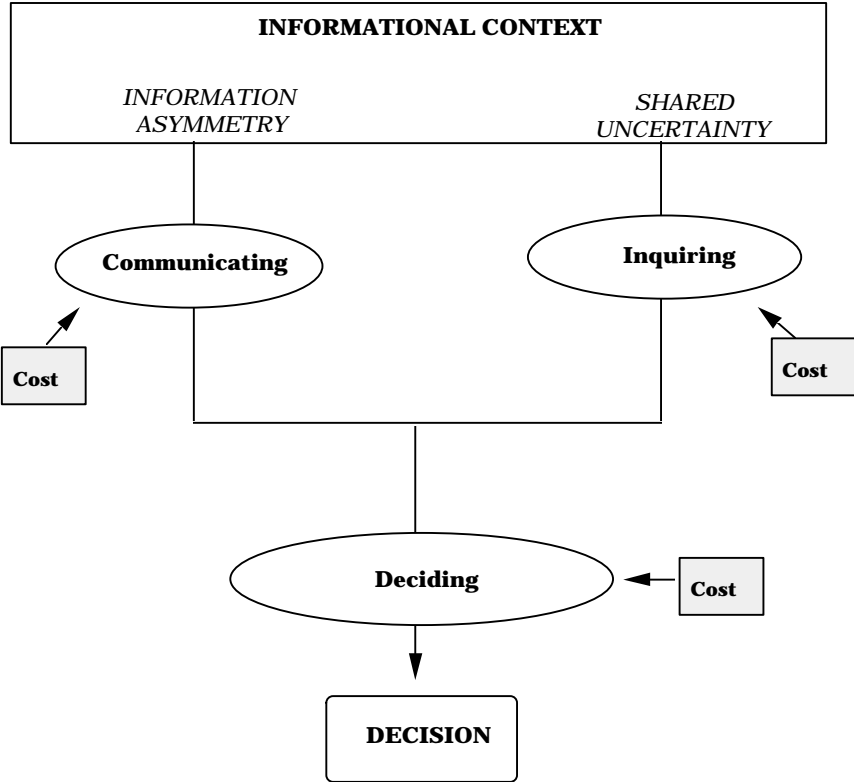

Figure 1 : The different decisional tasks
adapted from Marschak (1968)

These different tasks entail different kinds of cost, namely communication, inquiry and computation costs. Hence :

Information cost = inquiry cost + communication cost + computation cost

For a given amount of information to be collected, communication costs are always inferior to inquiry costs. Indeed, when inquiring, agents receive from the nature many information signals among which useful pieces of information have to be sorted out. When communicating, sorting has already been done (since inquiry has already been completed) so that information transfer is limited to useful messages (Arrow, 1984). It follows that :

(i) communicating is the information collection option to be used when the context is marked by information asymmetry between agents.
(ii) inquiry is the information collection option when agents are equally ignorant, i.e., in context marked by shared uncertainties.

We will use below this characterisation of informational tasks and related costs to deal with our problem.

Shared uncertainty versus information asymmetry : informational contexts in burden sharing

We can start by identifying the informational context in which burden sharing takes place. In burden sharing process, the nature of information to be processed is related to private pollution abatement costs. Let us assume that Ci, the private cost of the firm i, can be written as :

$$C_i = C + c_i$$

where C is the generic pollution abatement cost (which is the same for all the firms) and ci, the idiosyncratic pollution abatement cost. This assumption aims to take into account the fact that private pollution costs depend both on the generic cost of the pollution abatement technology and on the cost due to the insertion of the technology in a given production process. This latter cost is idiosyncratic because it is partly determined by specific features of production processes.

As far as inquiring is concerned, this characterisation of pollution abatement costs directly leads to three basic assumptions :

(1) The knowledge of C is a prerequisite for inquiring c_i. It simply refers to the fact that generic knowledge is necessary to acquire more specific information.
(2) The regulator cannot inquire neither C nor ci. It means that firms have an informational advantage of firms on the regulator about pollution abatement techniques.
(3) ci can only be inquired by the firm i whereas C can be inquired by whatever firms since ci is related to idiosyncratic features of i's production process.
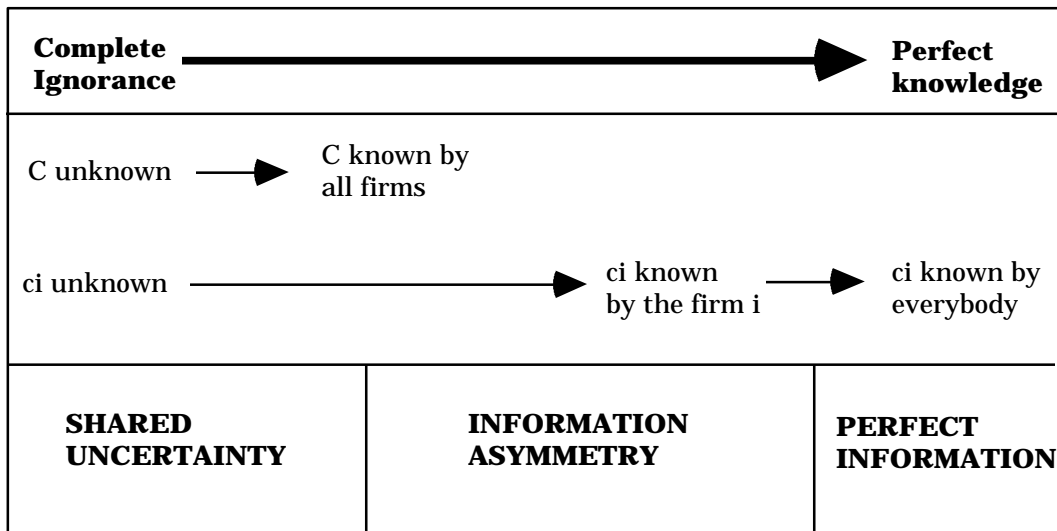
Figure 2 : Characterisation of informational contexts

These points lead to identify two contrasted informational contexts (figure 2) :

- When the ex ante uncertainty about pollution abatement techniques is high, it means that firms knows neither C nor c_i. The problem is to generate information about C. As C is observable by whatever firms, the context is one of **shared uncertainty**.

- When the ex ante uncertainty is lower, information processing only concerns c_i. As inquiring about c_i can only be carried out by the firm i, it leads to **information asymmetry**.

A characterisation of burden sharing schemes : the notion of information structure

Having characterised the context in which burden takes place, we need now to identify the institutional arrangements underlying VAs, command and control approaches and economic instruments. They are contrasted according to the location of pollution abatement decisions and communication patterns between the interested parties (i.e., the regulator and the regulated firms). Their respective information structures are presented in figure 3.
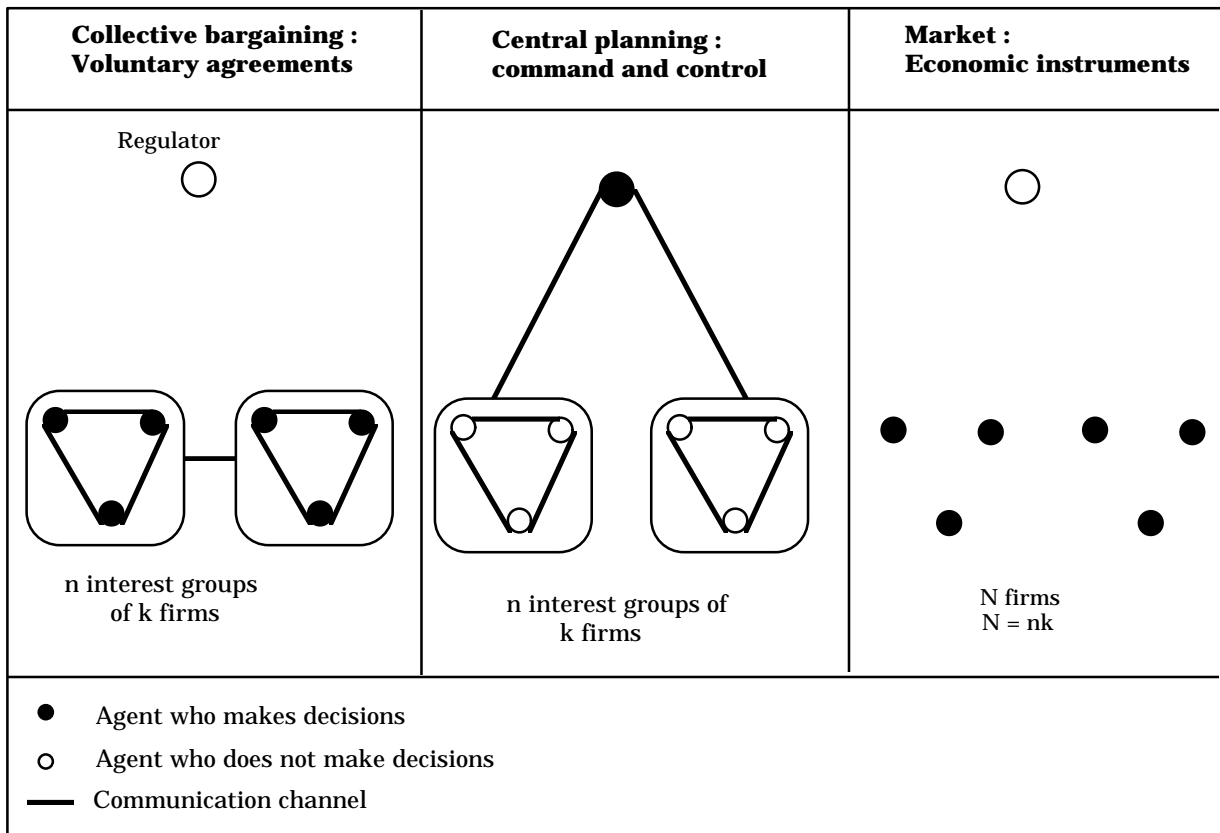
Collective bargaining : Voluntary agreements	Central planning : command and control	Market : Economic instruments
Regulator		

n interest groups of k firms

n interest groups of k firms

N firms
N = nk

•   Agent who makes decisions

○   Agent who does not make decisions

—   Communication channel

Figure 3 : Burden sharing of pollution abatement, the three information structures

Here are the main differences between the three arrangements :

- In the case of VAs and command and control approaches, firms are organised in interest groups when interacting in the burden sharing process. It is an empirical statement (see Lévêque, 1996, for instance).
- The three institutional arrangements are very different according to the location of decisions. Command and control approaches locate decisions at the regulator level whereas decisions are decentralised in the case of VAs and economic instruments.
- There is no communication at all in the case of economic instruments. Indeed, at the burden sharing stage, firms adjust their level of pollution activity in reaction to price signals without any communication between themselves or with the regulator. On the contrary, communication occurs in the two other cases. Communication flows are respectively vertical and horizontal for command and control approaches and VAs.

4. The relative informational efficiency of VAs

We can now assess the informational efficiency of VAs. The general logic is to examine the ability of the information structures of the burden sharing schemes to minimise information costs in the two informational contexts. In fact, the role of information structures in these contexts is very different. In the case of asymmetric information, the architecture of burden sharing scheme only affects communication and computation costs

since inquiry on ci is only carried out by firms on an individual basis. Therefore, the challenge is that of communication and computation cost minimisation.

In case of shared uncertainty, the problem is information creation. Inquiry can be carried out on a collective basis since information on C is generic and can be inquired by whatever firms. It follows that the role for burden sharing scheme refers to collective learning. In this case, information cost assessment is more complex since it includes communication, inquiry and computation costs. In the last part, the assessment will be carried out successively in the two contexts.

Assessment in contexts marked by information asymmetry

In information asymmetric context, the evaluation is limited to the measurement of computation and communication costs. We will proceed in the following way : we will make three simple assumptions on computation and communication costs and we will investigate their consequences on the relative information efficiency of the three schemes.

Assumption 1 : Computation costs do not depend on information structures
We have seen that the location of decisions is different in the three information structures. In particular, decision (and hence computation) is centralised at the regulator's level in the case of command and control approaches. We assume that such different patterns does not affect computation costs. In fact, it is based on two reasonable assumptions. First, we consider that individual firms and the regulator have the same computational ability. Secondly, we consider that computation exhibit constant returns, i.e. marginal computation costs do not increase (or decrease) when the amount of information to be processed increase. Consequently, sharing computational tasks between all firms (i.e. the case of VAs and economic instruments) or its concentration at the regulator level (i.e. the case of command and control approaches) entail identical costs. Concerning the efficiency assessment, it means that we can focus our analysis on communication costs.

Assumption 2 : communication costs increase with the number of communication channels. This classical assumption has been made by Arrow (1974). His argument is that the cost of using a communication channel is partly a fixed cost due to the initial investment to create the channel. It mainly refers to the immaterial investment of time and learning to be able to identify and use the information which is channelled.

	VA	Command and control	Economic instrument
Number of communication channels	$n(n-1)/2$, between interest groups $k(k-1)/2$ within each interest groups	n, between interest groups and the regulator $k(k-1)/2$ within each interest groups	0

Figure 4 : Number of communication channels in the three information structures

When comparing the number of communication channels in the three cases, the first obvious result concerns market burden sharing schemes (cf. figure 4). As there is no

communication (and hence no communication channels), communication costs are de facto nil. Turning now to VAs and Command and Control approaches, the difference between the two lies in the interaction between interest groups and the regulator : there are more communication channels in bargaining burden sharing schemes. It follows that Command and Control is more efficient than VAs (when n>2).

We can go a little bit further in our comparison of Command and Control approaches and VAs. In particular, VAs is more adversely affected when n increases than Command and Control approaches (i.e. the number of channels increases faster with n). If we consider the effect of k, there is no difference between the two schemes which are both negatively affected.

Assumption 3 : Communication costs between two agents increase with the degree of rivalry between them. This assumption aims to take into account the strategic problem when there is communication between agents who do not pursue the same objective. For instance, in the command and control scheme, when communicating with the regulator, the individual firm has an incentive to lie, i.e. to report to the regulator an over-estimated cost. Indeed this false report leads the regulator to allocate a private pollution abatement lower that the one the firm would have faced if she reported the truth. This problem is in fact very general. It can be stated as follows : communication between agents is subject to strategic manipulation when (i) the objectives sought by the emitter and the receptor differ, and (ii) the receptor's decisions influence emitter's gains. Models have shown that the more divergent the objectives sought are , or in other words, the more rival the emitter and the receptor are, the more difficult the communication (Crawford and Sobel, 1982). This is the sense of assumption 3.

In the burden sharing process, it is necessary to distinguish between inter-firm rivalry and firm-regulator rivalry. The inter-firm rivalry is rooted in the distributive dimension of burden sharing. Each firm wants the lowest private objective but, under the collective target constraint, it leads to transfer additional effort to other firms. Inter-firm rivalry is thus strong. On the contrary, the position of the regulator is that of referee (its goal is to minimise the collective abatement cost), and thus firm-regulator rivalry is weaker.

What are the consequences on informational efficiency ? It does not change anything for the market-based scheme since there is no communication. But as regards VAs and Command and Control approaches, it does matter. In fact, since VAs burden sharing rests on more intensive inter-firm communication than command and control approaches, it follows that communication strategic problem is more problematic.

To sum up, when information is asymmetric, VAs is always the worst solution whereas economic instruments are very suitable.

Assessment in contexts marked by shared uncertainty

As we have explained above, the challenge is that of collective learning in this context. order to identify the logic of collective learning. Let us identify the features of collective learning on a simple case. We consider two firms in a context of shared uncertainty. To reduce this uncertainty, they have to inquire on the generic pollution abatement cost C. Nevertheless, they can cooperate to collectively inquire instead of inquiring on an individual basis. This cooperation avoids to produce twice the same information. Let us assume that the information about C is separable in two pieces of information I_1 and I_2. Collective learning can be undertaken in this way : firm 1 and firm 2 respectively inquires

about I_1 and I_2, then they communicate to exchange information that has been produced (cf. figure 5).
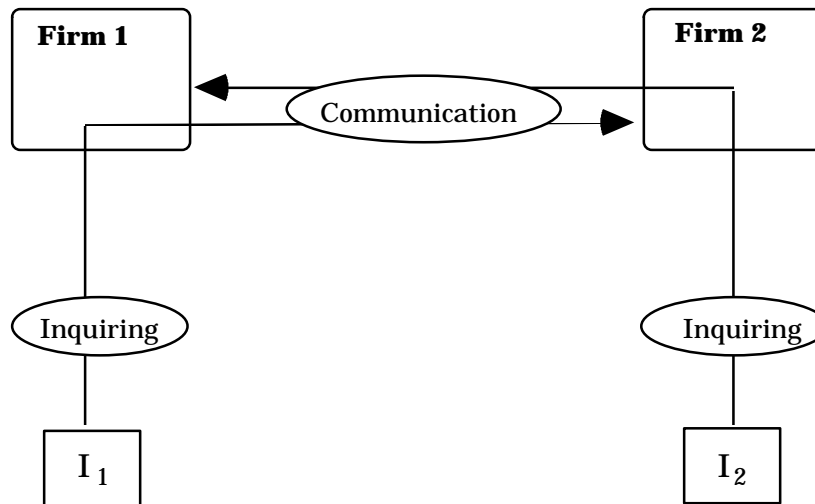

Figure 5 : Inter firm collective learning

Regarding information costs, collective learning saves inquiring costs but entails communication costs. In each case, the decision by firms to undertake collective learning will result from the balance between benefits in inquiring and costs in communication.
Nevertheless, the fact that inquiring agents are linked by communication channels in a given information structure is positive : it provides the *opportunity* for collective learning even though the opportunity might not used if communication costs are higher than inquiry-related benefits. The existence of this opportunity leads to another assumption :

Assumption 4 : In case of shared uncertainty, in a given information structure, the higher the number of firms linked by communication channels, the lower the sum [communication costs + inquiry costs]
This assumption leads to immediate results. In very uncertain context, market burden sharing scheme is inefficient since it excludes the possibility for collective learning. On the opposite, in VAs burden sharing scheme, all the firms are directly linked by communication channels, it allows extensive collective learning and renders VAs well suited in very uncertain context. Command and control only allows collective learning within interest group. Its informational efficiency thus stands between VAs and economic instruments.

Nevertheless, it remains that collective learning requires communication. In this respect, we have identified the effect of n and k on communication costs in asymmetric information context. This result is still valid here.

5. Conclusion : summary and discussion of the results

Figure 5 gathers our result about the relative cost efficiency of VAs :

	Voluntary agreement	Command and control approach	Economic instrument
Asymmetric information	**0**	*	**
Shared uncertainty	**	*	**0**
Non concentrated sector	**0**	**0**	*
High inter-firm heterogeneity in pollution abatement costs	**0**	*	*

** means that the concerned burden sharing scheme is very efficient in this context, * means an intermediate efficiency and 0 means that it is not cost efficient. Comparison of efficiency results of the different lines of the table is senseless.

Figure 5 : Summary of the results

We have transformed n, the number of interest groups and k, the number of firms within each interest groups into two more operational variables: respectively the degree of inter-firm heterogeneity in pollution abatement costs (which is the cause of differentiation of industry into several interest groups) and the degree of concentration of the industrial sector (which directly affects the size of interest groups).

VAs are cost efficient in the following context : very large shared uncertainty about pollution abatement techniques, concentrated industrial sectors in which the heterogeneity in pollution abatement activities is low. In this respect, voluntary approaches which has been used to promote a move of traditional waste management scheme towards recycling (packaging recycling, car recycling) seem well suited. Indeed, this policy area is characterised by important changes in the pollution abatement activities and thus gives birth to large uncertainties. Concerning CO_2 reduction agreements in high energy consuming industries, we can be more suspicious about the cost efficiency of voluntary approaches. As a matter of fact, in these sectors, given the weight of energy cost in total production costs, firms have paid much attention to energy saving activities for a long time. It can be assumed that the nature and the cost of energy saving techniques are well known by each firm and that the informational context is asymmetric.

The theoretical approach we have carried out in this paper is very different from the traditional (Pigovian) approach. We have not investigated the cost effectiveness but the cause for cost effectiveness : the cost of information processing about pollution abatement techniques undertaken by the agents (the regulator or the firms). Informational efficiency covers the two Pigouvian dimension of cost-effectiveness, namely allocative efficiency and productive efficiency. Indeed, good quality in information enhances allocative efficiency but also productive efficiency, i.e. the cost efficiency of the individual firm when it undertakes pollution abatement. In this regard, good performances of VAs in uncertain context are mainly related to what Pigovians refer as productive efficiency. When using VAs, intense collective learning improves information of the firms and allows them to implement their private pollution abatement objectives at a lower cost. However, our

approach remains exploratory. In particular, it is very sensitive to the assumptions which are made about the nature of information which is processed and the nature of the different information processing systems. More empirical works remain to be done about informational aspects in VAs to improve these assumptions.

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