Bureau d'économie théorique et appliquée (BETA)
UMR 7522

Documents de travail

Documents de travail

« Prevention and Compensation of Muddy Flows : Some Economic Insights »

Auteurs

Sandrine SPAETER, François COCHARD, Anne ROZAN

Document de travail n° 2006–**29**

Octobre 2006

Faculté des sciences économiques et de gestion
Pôle européen de gestion et d'économie (PEGE)
61 avenue de la Forêt Noire
F-67085 Strasbourg Cedex

Secrétariat du BETA
Christine Demange
Tél. : (33) 03 90 24 20 69
Fax : (33) 03 90 24 20 70
demange@cournot.u-strasbg.fr
http://cournot.u-strasbg.fr/beta

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

UNIVERSITÉ LOUIS PASTEUR STRASBOURG

Prevention and Compensation of Muddy Flows: Some Economic Insights[1]

Sandrine SPAETER[2], François COCHARD[3] and Anne ROZAN[4]

October 25, 2006

[1]This study is part of the work done by the group GERIHCO (GEstion des RIsques et Histoire des COulées boueuses / Risk management and history of muddy flows) in Alsace (North-East of France) in collaboration with the Rhin-Meuse Water Agency. It is also integrated in a national project on erosion from the French ministery of ecology and sustainable developpment (MEDD - programme RDT). The Rhin-Meuse Water Agency, the Louis Pasteur University of Strasbourg and the French ministery provided the financial support. Our colleagues from this network, and especially Anne-Véronique Auzet and Philippe Martin, are acknowledged for many useful discussions and comments.

[2]Corresponding author. BETA, UMR 7522 CNRS/ULP/Nancy-Université. Mailing address: BETA, 61, Avenue de la Forêt-Noire. F-67085 Strasbourg. Phone: +33 (0) 390 242 076. Fax: +33 (0) 390 242 071. E-mail: spaeter@cournot.u-strasbg.fr

[3]LERNA, Université Toulouse 1. Manufacture des Tabacs - Bat. F, Allée de Brienne, F-31000 Toulouse. E-mail: francois.cochard@univ-tlse1.fr

[4]GSP, UMR Engees-Cemagref, 1 Quai Koch - BP 61039, F-67070 STRASBOURG. E-mail: anne.rozan@engees.u-strasbg.fr

Abstract

Recent surveys report the increasing number of muddy flows in many areas, and point out the fact that agricultural practices (among others) influence significantly the risk and severity of muddy flows. In this paper, we investigate the economic incentives that can be given to the farmer to adopt different practices. We propose an original economic instrument that entails an 'ambient tax', voluntary revelations and a compensation fund. Because of the authorities' difficulties to be informed of each farmer's individual efforts, the tax cannot depend on the individual but on the collective level of efforts. However, each agent may lower his tax payment by revealing his individual efforts to the regulator so that high efforts may be rewarded compared to low ones. The tax revenue is used to supply a fund that is dedicated to the compensation of victims if a muddy flow occurs. hence it is possible to simultaneously increase the incentives for farmers to adopt more environmentally friendly practices and to improve the compensation of victims without mitigating their incentives to protect themselves against the risk of muddy flow.

Key Words: muddy flow, natural disasters, economic incentives, ambient tax, insurance, compensation fund.

JEL: G22, H21, H23, H3, Q2, Q54

1 Introduction

This paper aims at considering the economic issue of muddy flow risks. We propose to explore the specificities of such risks and to present some "pistes" that could be followed in order to mitigate them. All stakeholders are involved at different steps in the decision process and our discussion is never deconnected from the physical aspects related to muddy flows. In particular, not only the farmers, but also the inhabitants, take part in a compensation fund, which characteristics and properties will be analyzed.

Muddy flows[1] have been the subject of many studies in different disciplines (agronomy, hydrology, morphology, physical, geography, ...). Concerning the physical processes and the climatic aspects, much is done to understand how and why they occur. In particular, one important aspect of muddy flows deals with the role played by the agricultural practices and with the efficiency of some practices in the mitigation of muddy flow risks. Recent surveys report the increasing number of muddy flows in many areas, and point out the fact that those problems are not only due to natural events, but also to land occupation and human activities (see for example the report by the French Ministry of Environment and Agriculture, 1996). Both agricultural and domestic activities play an important role in the occurrence of muddy flows by affecting topography and soil, and suppressing various types of 'buffer zones' such as hedges, ditches, water bodies, wetlands, forests, fields. Many studies have been carried out on the agricultural practices and their respective efficiency on soil hydrology and mechanics, and it seems that some of them are better than others (no tillage, double drilling of small grains, ...) to limit soil detachment. Even though all complex aspects of muddy flow are not yet well understood, implementing cropping systems that induce less risk of runoff and soil erosion becomes urgent. Because of a lack of information, of communication between the different groups interacting together (scientists with decisionmakers, farmers with de-

[1] See Auzet, Boiffin, Papy, Maucorps, and Ouvry (1990), Helming, Auzet, and Favis-Morlock (2005) and Auzet, Heitz, Armand, Guyonnet, and Moquet (2005) for a detailed description of this phenomenon, Boardman and Poesen (2006) for erosion soil in Europe and Auzet, Bissonnais, and Souchère (2006) for specific insights about the french issue.

cisionmakers, farmers with farmers, ...), such implementations may fail to work. Then analyses of the sociologic relations between the individuals or the groups of individuals may help to emphasize and to understand the locking points[2].

Cost-benefit analyses are also carried out in order to evaluate the social cost of muddy flow, taking into account not only claims of the inhabitants of a damaged area, but also the loss of intrinsic value of ground when soils are detached and transported from the lands to the roads or dirt tracks (for recent works see for instance Kuhlman, 2006 and Happe, Damgaard, Osuch, Sattler, Zander, Uthes, Schuler, and Piorr, 2006). Knowing all this information about cost, benefit, networks, characteristics of farms, soils, and so on, the aim of the economic instrument is to "convince" farmers to change their practices. However, because any change in individual practices that improves the social welfare may create some distortions at the individual level, the agent may not be willing to change his practices or his technology without either being compelled or having sufficient incentives to do so. In the context of muddy flow and, more generally, when dealing with environmental risks, even a harch legislation does not permit a regulator to compell agents to opt for the "right" behavior especially because he cannot observe all the actions decided by the agents. The work of the economist is therefore to build some economic instruments that create such incentives without the need of full information about individual actions.

Efficient tools must be such that modifications in the practices be valuable for both the farmers and the citizens, in the short term but also and especially in the long term. About this point it is often believed that subsidies are the best way to deal with technology change. Moreover, it is often thought that subsidies should be put in place indefinitely, otherwise one might observe a surrender of the new practices because of a lack of financial support. Unfortunately, from a financial point of view it is too costly to sustain such a policy for a long time.

[2]In this spirit, sociology is becoming a significative cornerstone in the comprehension and the mitigation of muddy flow risks through the work done on the functioning of the involved networks. See for instance Fry (2005) and Mathieu and Joannon (2005).

One point we want show is that subsidies are not the sole instrument that may be implement in the agricultural sphere and, most importantly, that economic tools (including subsidies) should not be systematically seen as very long term, and then very costly, solutions. To do so, we choose to deal with the normative approach of economics: we are focusing on “what is the best” knowing the different constraints. In this approach we differ from the economic studies that consider the Coase (1960) conjecture related to property rights and the transaction costs related to the relations between the regulator and the farmer. We are focusing on the polluter-pay principle formally established at the international level in 1972 by the OECD. A straight application of this principle often leads to the implementations of taxes on goods, production or practices that deteriorate the environment. But, for reasons detailed below, standard taxes are not the good way to limit muddy flow risks, and a more flexible regulatory policy will be proposed.

Before going further in the introduction, let us tell a word about the elements that economics take into account when defining risk, and especially muddy flow risks. As in other disciplines, the frequence of occurrence of an event and also the consequences it induces are among the most important elements in random processes. Nevertheless, when dealing with events that may concern simultaneously a large population (natural hazards, technological accidents, ...), the degree of correlation between the risks borne by the individuals is also an essential element because it impacts the efficiency of the risk mitigation policy to be implemented. Indeed, risk diversification over a large population no longer matters if everybody is harmed at a same date and by an identical event. Individual motivations to invest in protection and/or prevention measures also depend on wether the individual is alone to suffer a damage or if he belongs to an harmed population. Muddy flow risks belong to this category, with high correlation between the agents. Even if their financial consequences are, often, not so huge as those observed for some large-scale risks (eartchquake risks for instance), they are considered by the economists as no standard risks and, thus, they cannot be studied such as classical risks (house, car, domestic risks, ...).

In this paper, we are considering *ex ante* risk mitigation and *ex post* compensation. A specific economic instrument is investigated: the ambient tax. This instrument first appears in the economic literature in Segerson's (1988) work and consists in fixing a tax no longer based on individual emissions of pollutant (which are often difficult to be known by a regulator) but with respect to the ambient level of pollution in the affected area (a lake, a river, the groundwater, the air, ...). We discuss the usefulness of such a tool in the frame of risk rather than of pollution. Our aim is to propose an environmental policy that gives farmers sufficient incentives to change their practices and also to inhabitants to protect their goods and themselves against muddy flows. This policy is based on an ambient tax to which we add the possibility for the farmer to reveal some information about his own practices and, by doing so, to be exempted from, at least part of, the ambient tax. Such an instrument has several positive characteristics and seems to be an efficient way to deal with diffuse pollution in a sense that we will precise in the text. Still we explain which adaptations should be made in order to adapt it to the muddy flow issue and we also focus on experimental economics. This investigation field is rather recent in economics and allows to test, under specific conditions, the predictions of economic (mostly game theoretic) models. In particular, experimental economics enables us to test the efficiency of some economic tools before they are implemented in practice. This is especially useful when no empirical data are available, which is the case for new instruments.

In the economic literature, the 'double dividend conjecture' states that Society may benefit twice from an environmental policy based on taxes. First, taxes induce more internalization of the risk of pollution by the agents and give them some incentives to reduce it and, second, taxes can increase the revenue of some agents by being redistributed within the sector concerned by the environmental policy. In the second part of this work, we focus on coverage aspects and we are to some extent rather close to this conjecture. Indeed we analyze the characteristics of a compensation fund that would be supplied with the ambient tax and devoted to the compensation of victims of muddy flows. Such a system is interesting owing to the fact that victims are directly compensated by the agents the activities of which, combined with specific climatic conditions, have generated the damage and, as we will explain it in the paper, it provides some risk mutualization to the farmers. Moreover, the level of the available funds are directly connected to the magnitude of the risk of muddy flow.

While our reflexion was being constructed, many discussions took place with researchers from other disciplines in agronomy, hydrology and morphology, geography, sociology and history of sciences. This allowed us to bring our theoretical reflexions face to face with empirical and physical facts as often as possible.

The paper is organized as follows. Section 2 presents the theoretical insights of the ambient tax and, then, it discusses the role that experimental economics play in evaluating its economic efficiency. Section 3 deals with the compensation of victims after the realization of a muddy flow risk. The characteristics of such a risk and its difference compared to other large risks are presented. Then we propose a new management mechanism that entails an ambient tax, voluntary revelations and a compensation fund. We show how it is possible to simultanously increase the incentives for farmers to adopt more environmentally friendly practices and improve the compensation of victims without mitigating their incentives to protect themselves against the risk of muddy flow. Section 4 concludes the paper.

2 The ambient tax mechanism: Theoretical aspects and empirical insights

In this section we first discuss the type of policy scheme that should be used to address the muddy flow issue and suggest resorting to an ambient tax mechanism, which was initially developed to handle the NonPoint Source Pollution (NPSP) issue. Second, we compare the NPSP and the muddy flow issues in order to see how the ambient tax scheme could be adapted to the latter setting. Finally, we present briefly the many experimental studies that have been carried out to investigate the practical efficiency of the instrument.

2.1 Theoretical aspects

Our goal is to induce the agents whose activities have an impact on the occurrence of muddy flows to adopt better practices. A straightforward way to provide such incentives is to reward good practices through subsidies and punish bad practices through taxes. However that kind of regulation (which is directly related to the traditional 'pigovian' taxation first proposed by Pigou in 1920) is likely to be too costly to be applied to the muddy flow issue. Indeed, it requires the regulator to observe all the practices that have an impact on muddy flows. However, many of the agents' practices are likely to be difficult—if not impossible—to be monitored by the regulator at a reasonable cost. For example, while it may be easy to observe the type of crop in a field, or the area of cultivated land, it is less easy to observe a farmer's tillage practices or his way of fertilization.

2.1.1 Similarity with the NonPoint Source Pollution (NPSP) issue

A very similar problem occurs in the field of NonPoint Source Pollution (NPSP), which is a specific type of pollution where the regulator's information is restricted. The pollution of a specific area (e.g. a lake) is typically said to be *nonpoint* if the polluters' individual emissions that generate this pollution are fully or partially unobservable by the regulator at a reasonable cost (see among others Tomasi, Braden and Segerson, 1994). For instance, pollution of the ground water by nitrates is a NPSP issue. NPSP is defined in opposition to *Point* Source Pollution, in which polluters and their emissions are known. The concentration of pollution in the affected area is called the 'ambient pollution' level. This lack of observability of polluters' emissions stems from several causes. Pollutants follow indirect and diffuse pathways from the sources to the environmental recipients (air, water or soils) and their fate is highly dependent on weather conditions. Dischargers are numerous and often of small size[3] (households, farms, ...). Sometimes they are even mobile, (e.g. cars in urban areas). Because of these unability to observe perfectly each polluter's individual emission, traditional environmental policies aimed at regulating individual emissions cannot be used to address NPSP questions. Then one must seek other observable elements on which to base regulations.

The most straightforward candidates for regulation are the 'inputs', i.e. all the factors that a firm uses to produce. They are taken in a very wide sense, including both material inputs like the machines, buildings, factories, fields, labour, energy, etc. as well as immaterial inputs like practices or technologies. Hence a first possibility would be to control input use by introducing 'input taxes' on those inputs which increase pollution, and 'input subsidies' on those inputs which reduce pollution (Griffin and Bromley, 1982, Shortle and Dunn, 1986, Shortle and Abler, 1994). However, as pointed out by Braden and Segerson (1993), the instruments requires the regulator to be able to monitor all the inputs that have an impact on pollution, which is obviously likely to be too costly. Thus we are back again to the point of imperfect information.

Finally the similarity between the muddy flow and the NPSP issue appears clearly:

- A muddy flow harms some agents and is (at least partially) caused by some other agents' bad practices, though the latter do not pay for this damage. This 'negative externality' suffered by some economic agents justifies some intervention by other agents (not systematically the State) to regulate the situation.

- Many types of practices may have an impact on the occurrence and severity of the

[3] Examples of NPSP can be mostly found in domestic and agricultural areas. Large quantities of fertilizers (containing nitrogen) are spread out in fields for higher yields. Nitrogen is partly absorbed by crops but is partially transported away to surface or ground waters, or it can evaporate into the atmosphere. Pathways are complex and affected by the nature of the soil, topography, weather conditions, etc. An exhaustive observation of all those elements is virtually impossible. Furthermore, individual emissions not only depend on those 'natural' parameters, but also on the polluters' practices. For instance, nitrogen leaching can be more or less important according to the period of spreading. Polluters' practices are clearly difficult to monitor.

flow, some of them being especially difficult to monitor by the regulator. Moreover, as NPSP, muddy flows are due to the conjonction of several agents' activities, so that it is hard for the regulator to separate the responsibilities of each of them. Hence he cannot resort to an individual regulation of practices without having to carry out expensive individual audits.

- Random factors such as weather conditions have a significant impact on muddy flows, just as in NPSP problems.

2.1.2 The usefulness of an ambient tax

To adress the NPSP issue, economists have developed a specific policy scheme. Since individual actions are difficult and costly to be observed and drawing on the advances in agency theory applied to teams (see Holmström, 1982), Segerson (1988) and Xepapadeas (1991) suggest to use the ambient level of pollution as a consistent basis for the tax[4]. Since the ambient pollution level depends on the individual emissions, such a tax is able to induce each polluter to choose the actions that will decrease this level throuh individual emission reduction.

Our claim here is that a variant of such a policy scheme can be relevant for the regulation of muddy flows. Instead of trying to directly observe and control the agents' practices, the regulator should introduce a tax scheme based on the *results* of their practices, i.e. the environmental quality, and more precisely here the damages generated by a muddy flow. Such a policy scheme should induce each agent to improve his practices because by doing so he reduces the risk of being liable for a large tax. Of course this policy instrument requires the regulator to be able to provide an economic assessment of the damage due to a muddy flow. It should be noticed that to date such economic assessments are usually not carried out or are not carried out with sufficient care.

[4] Hansen (1998) and Horan, Shortle, and Abler (1998) propose taxing the *damage* generated by ambient pollution, but the principle of their schemes remains the same in a general setting.

2.1.3 Interaction, rationality and complete information

An ambient tax is a *collective* mechanism, to the extent that the tax an agent has to pay not only depends on his *own* practices, but also the others' practices since the damage also depends on the others' efforts. This implies that when making his decisions, an agent has to take into account what it believes the others will do[5]. The polluters' decisions are now interdependent, or put differently, the agents are in a *game* as defined by game theory. In such a game, it is generally assumed that rational agents choose their welfare-maximizing decisions given the information they have on others and on their environment. Based on that assumption, game theory is able to propose different solution concepts, i.e. to give reasonable predictions to rational agents' decisions. One of the most general solution concept is the so-called *Nash equilibrium* (Nash, 1950). The agents' decisions form such an equilibrium when each agent's decision is individually optimal given the other agents' decisions. Put differently, in a Nash equilibrium, no agent has any incentive to *unilaterally* change his decision. Since the regulator can compute this equilibrium, he is able to calibrate the tax so that at the equilibrium, each polluter makes the decisions that are *socially desirable*. A necessary condition for this is that the regulator provides agents with *complete information*, that is, with all the information they need to make optimal decisions. In particular, an agent should be informed of all the other agents' characteristics (i.e. the cost of their efforts to adopt better practices) in order to be able to anticipate their decisions. Furthermore, an agent should know the impact of his decisions on the environmental quality in order to be able to evaluate the impact of his decisions on the level of the tax (such informations should be at least partially provided by scientific investigations and disclosed to the agents via the regulator). Hence, if agents behave rationally and have complete information, the instrument should be efficient.

[5]For example, if a polluter thinks that the others will not emit much, then he may anticipate that the ambient pollution level will be low so that the level of the tax will be low as well, therefore he might afford to emit more. But the impact of such a behavior can be counterbalanced by a reputation effect. We will come back to this argument later on in the paper.

The assumptions of rationality and complete information from the agent's side are not as strong as they seem to be at first glance. It is true that rationality is never perfect in the real world, to the extent that errors are possible. However, errors may not be systematic and therefore cancel out on average. The assumption of complete information seems plausible if polluters are located in a small area, know and can monitor each other, and can possibly communicate (e.g. farmers in a small region). This points is strongly linked to scale considerations, which are discussed in Section 3. Actually, rationality and complete information might be rather reasonable assumptions when dealing with the muddy flow issue. Even so, several authors (i.e. Hansen, 1998 and Horan, Shortle, and Abler, 1998) have expressed skepticism about their validity and pointed out the necessity of empirical studies. Many such studies have been carried out thereafter in order to address these worries. But before presenting them in subsection 2.3, let us show in the next subsection how the ambient tax mechanism can be adapted to the muddy flow context.

2.2 Adaptation of the ambient tax to the muddy flow setting

There are some differences between the muddy flows and NPSP problems, justifying an adaptation of the ambient tax accordingly to the following points:

- Contrary to non-accidental and diffuse pollution, muddy flows occur at some random dates and not during a given period, which suggests that the regulator should choose between two kinds of tax schemes. If he wants the tax payment to occur at fixed dates then, when evaluating the level of tax payment, he cannot wait until a muddy flow occurs. Thus a possibility is to assess the probability and damage of the flow for the forthcoming period and to introduce a tax based on the expected damage of the flow. On the contrary, if the regulator wants the tax payment to be directly related to the real damages of a particular flow, then the tax can only be levied after a flow has occured. In this case, the ambient tax mechanism applied to muddy flows might be regarded more as a penalty than as a tax system. Because of the randomness of the muddy flow events, tax payments will be random as well, so that risk-preferences are likely to play a significant role. Indeed, if agents are risk-averse[6], they will not react similarly, depending on the "riskyness" of the environmental policy they have to follow.

- Muddy flows often give rise to very important damages, and are often regarded as 'natural disasters'[7]. This implies that the level of the tax may reach very high levels in some cases if it is evaluated *ex post* on the basis of the real damage. And it may give rise to the bankruptcy of some agents that are liable for the tax. That problem was already recognized in the NPSP situation, but it is likely to be even more serious here. The solution is typically to diminish the level of the tax payment by a lump-sum (i.e. fixed) amount (it is sometimes said that the ambient tax is combined with a lump-sum subsidy). Since that amount is fixed, it is well-established that it does not change the incentives from an economic point of view and the instrument remains efficient. Of course, if the fixed amount is very high, the agents may even actually earn a subsidy instead of paying a tax if the damage is small. Together with the argument related to risk smoothing, this point is finally an argument in favor of a tax that is implemented *ex ante*, on the basis of the level of risk.

- Responsibilities are often shared among various types of agents, such as the local or national authorities (who are responsible for the location of buildings and the construction of roads), firms, farms and also citizens. Farmers are generally recognized as having large responsibilities in the occurrence of the flows, so that they should be liable for the ambient tax. However, they should not be the sole payers since the level of the damage is also due to the citizens decisions. This argument

[6] An agent is risk averse in an economic sense if he is willing to pay to obtain the mean gain (or loss) of a given situation without any possible fluctuation around this mean value.

[7] In France, villages or towns having suffered a muddy flow event have the possibility to obtain the natuaral disaster state ('*Etat de catastrophe naturelle*') thanks to a decree. If the decree is adopted, then victims benefit from the solidar, and compulsory, compensation programme related to natural hazards.

is formalized in Section 4.

The latter two points emphasize the acceptability issue that can be associated with the implementation of an ambient tax for the regulation of muddy flows, and they point out the difficulty of implementing a crude ambient tax. Acceptability issues have already long been discussed in the field of NPSP, but they are likely to be even more important in the muddy flow setting.

Another possibility to address the acceptability problem is to introduce instruments that are less dependent on the collective effort and more dependent on individual efforts. This can be done by giving the agents the opportunity to *reveal* their efforts, and then checking the revelations through individual inspections. As said previously, the regulator cannot carry out systematic individual monitoring because it would be too costly. However, it is well known since Becker (1968) that random inspections are sufficient to provide correct incentives: lower inspection probabilities can be substituted by higher tax payments. Xepapadeas (1995) and Kritikos (2004) suggest using such random audits along with ambient-based schemes.

We suggest amending the ambient tax mechanism in the spirit of those specific schemes. Hence the mechanism that we propose in Paragraph 3.2. uses the reputation effects that may arise in small groups in order to create sufficient incentives for an agent to behave in adequation with the environmental recommandations. Moreover, by investing in new practices, the farmer will be able to signal himself to the authorities in order to benefit from a reduction in the ambient tax.

To summarize, an ambient-based tax mechanism is likely to be efficient in mitigating the muddy flow problems. However, since our point was essentially theoretical until now, a legitimate worry is the actual efficiency of such an instrument in the real world. Again, we have good reasons to be optimistic in that respect as well thanks to the numerous experimental studies that have been carried out in order to test the performance of the scheme in the NPSP context. This is what we detail in the next subsection.

2.3 Laboratory experiments

To our knowledge, ambient-based schemes have rarely been implemented in the field yet.[8] This means that very few real data are available to assess the practical efficiency of the instrument. Besides, even if the instrument had already often been introduced in the real world, data might have been difficult to collect or to interpret. Such as in experimental sciences, economists have overcome the obstacles inherent in the use of real world data by collecting data in a controlled environment, i.e. the laboratory.[9] There are three reasons for using experimental economics (Shogren, 2004): to test theory, to look for patterns of behaviour and to use the lab as a testbed for economic design. Thus it allows us to build new mechanism designs and to test their efficiency.

Concerning ambient tax mechanisms, several experimental tests have been carried out to provide insights on its practical efficiency in the NPSP setting.

All those experimental studies adopt the following standard methodology. Upon arriving in the lab, each subject has first to read detailed instructions describing the decisions he has to make during the experiment. At the end of the experiment, each subject receives a cash payment which depends on his performance during the session. Performance-based payments are often preferred to lump-sum payments because they are usually regarded as providing better incentives: they directly depend on the subject's decision.

An experimental session is composed of several periods (typically between 10 and 40 periods). Subjects play the role of firms which emit pollution. It should be noticed however that most experiments are non-contextualized, which means that they use a neutral terminology. For example, subjects are not told that they play the role of *firms* that *emit pollution*. Neutral words are used instead, such as *subjects* instead of *firms*, *tokens* instead of *units of pollution*, *payoff* instead of *profit*. While this practice may look

[8] An exception is presented in Ribaudo, Horan, and Smith (1999).

[9] The first experimental economic works begun in the early 1950s. For a presentation of the standard methodology and the main domains of application, see for example Davis and Holt (1993), and Kagel and Roth (1995).

queer to non-specialists, it is often preferred by experimenters because it allows drawing more general conclusions from experiments, and it avoids confusing the subjects who focus only on the monetary incentives and not on the specific context that would be suggested. However there are also arguments in favor of contextualization, depending on the problem at hand. Contextualization can be particularly consistent with our study on the muddy flow issue, where reputation and personal feelings about the environment affect the preferences of the agent. Actually 'field experiments', which resort to contextualization and 'real' agents, are now emerging in experimental economics. They must be considered as a suitable way to deal with the test of the ambient tax efficiency in the context of muddy flows. Furthermore, unless otherwise stated, no communication is allowed among subjects. They are isolated from each other in partitions, so that they cannot see or hear each other. The only information the subjects get on what the others do is the sum of their invested tokens (sum of their emissions) at the end of each period. Avoiding direct communication allows the experimenter to get more control on the reasons why subjects are making their decisions. Communication can be introduced in the lab, but this should be done carefully to avoid losing too much control. For example, direct verbal communication can lead to psychological effects such as intimidation, seduction, etc. that the experimenter might not be aware of. However, it should be noticed that introducing communication can be relevant still in some studies (such as ours) to the extent that polluters are likely to know each other and meet frequently in the real world.

Several variants of the ambient tax have been tested in the lab, and a detailed description of all the collected results is beyond the scope of this paper. We shall focus here on the important following result **:**

Ambient taxes induce a level of ambient pollution close to the level desired by the regulator in charge of maximizing the social welfare[10]*. Nevertheless, this level is achieved at*

[10] In a Society composed of farmers and inhabitants, the social welfare encompasses the profit of the farmers plus the wealth of the inhabitants. If more agents are present (like lenders, ...), then their wealth are also considered in the social welfare.

a cost which might not be the lowest possible one. Indeed the highest emission reductions are not always observed in more cost-effective firms, i.e. those firms in which abatement is the least costly.

This general result has been obtained in several studies (Cochard, Ziegelmeyer and Bounmy, 2005, Cochard, Willinger and Xepapadeas, 2005, Alpizar, Requate and Schram, 2004, Poe, Schulze, Segerson and Vossler, 2004, Camacho and Requate, 2004 and Vossler, Poe, Segerson and Schulze, 2002), and was further found to be robust to the introduction of randomness into the ambient pollution function (Spraggon, 2002), which reflects natural variability (weather conditions). Translating this test into the muddy flow setting, it suggests that the inherent randomness of a muddy flow event should not decrease the efficiency of the ambient tax.

Nevertheless the instrument has been found to be significantly less efficient when subjects have different cost functions (Spraggon, 2004). Such an heterogeneity is of course likely to be present in the real world, and Spraggon expected that it would reduce the efficiency of the instrument because it makes the decisions of the subjects more difficult to make. Indeed, remember that when an ambient tax is implemented, subjects have to anticipate what the others will do to take their own decisions; obviously that task is more complex if the others have different characteristics than them, even though those characteristics are known. This problem might also occur in the muddy flow context if agents have heterogenous characteristics. Still there the scale issue is important, and the degree of homogeneity of the selected set of farms, or lands, concerned by given policy shall be an essential argument.

To conclude, the experimental studies show that the ambient tax is a promising policy instrument although it should still be improved. Possible improvements are the ones already suggested in the previous subsection, that is, introducing the opportunity for polluters to reveal at least part of their individual emissions, and taking advantage of reputation effects.

Because the system we propose will also take into account *ex post* considerations, we now turn to the compensation aspects of the damages due to muddy flows.

3 Insuring natural disasters

Up to now, we were interested in what should be implemented *ex ante* to reduce the risk of muddy flow. But risk management also implies that regulators focus on *ex post* claims. Once a muddy flow occurs, it is important to know how the victims are, or should be, indemnified not only because they are victims and they suffer from negative externalities, but also because the way they are compensated in has a non neglectible impact on how they behave before the catastrophe. Our reflexion is divided in two steps. First, we explain why natural hazards, and in particular muddy flow risks, cannot be managed such as standard risks (those related to car driving, to the house, to health,...). Second, we propose a new way to compensate victims of muddy flow in a given area by combining the ambient tax with risk mutualization.

3.1 How damages should be compensated?

3.1.1 Correlation and risk transfer

Large risks, which entail technological risks, environmental risks due to anthropic activities and, above all, natural catastrophes, display some differences when compared to more standard risks (car insurance, house insurance, ...) that make them difficult to be considered by classical tools of insurance. Indeed through the risk transfer mechanism, an agent - the insurer - buys a risk from another agent -the insured - at a negative price - the insurance premium. The former is able to accept many risks and, thus, to play the role of an insurer for many individuals, if these risks are independent. Independence means here that neither the severity nor the frequency of the potential damage for one individual is correlated to the damage or to the frequency of another one, so that the insurance premia paid by some individuals may cover the indemnities paid to others at a given date. This is no longer the case when dealing with large risks since all individuals in a same area face similar risks and will, in the case of an accident, present their claims simultaneously to the insurer. In such a context, the financial situation of the insurer may be deteriorated and, in some cases, he may be pushed into bankruptcy. To correlation (or dependance) one must add the fact that consequences of a damage may be huge for Society. Lastly, because of their low frequency (compared to other risks), insurers do not always have sufficient statistics to well define the risk and to estimate a fair insurance premium. Moreover, they do not have perfect and complete information about the behaviors of the insured persons and in some cases, in particular for muddy flows, the behavior in terms of self-protection (respectively prevention) affects the level (respectively the probability) of a loss[11].

3.1.2 Mutualization and the law of large numbers

Concerning natural hazards, correlation is one of the most important issues that insurers have to deal with because the well-known mutuality principle (which is the second important principle in insurance economics) becomes difficult to be applied in such a context. Indeed, risk mutualization means that risks from a given sector or a given group are gathered together and that a percentage of the agregate risk (equal to the sum of all individual risks) is redistributed to each individual within the group. This percentage does not depend on the initial individual risk, but rather on the attitude towards risks of the concerned agent. Moreover, when individual risks are independent (such as in car insurance, house insurance, health insurance), the agregate risk may be very small, even zero, if the number of individuals is sufficiently large in the group. The law of large numbers induces, finally, a decrease in the variance of the agregate risk: it tends towards zero (See the appendix for a simple demonstration).

This property does no longer hold if risks are dependent each others. To the variance, one must add the covariance matrix and, in the case of natural risks, individual risks present some positive covariance. Hence, the law of large numbers does no longer work here and the agregate risk remains a random variable. But, the aggregate risk could be

[11] Prevention deals with activities carried out by the agent in order to reduce the probability of damage (like driving carefully for car risks or buying one's house in a non liable to flooding area), while self-protection is relative to activities that induce a decrease in the level of damage if any (like fastening one's seatbelt, or building a wall around one's property).

mitigate by influencing the actions of the agents that affect either the probability or the level of the potential damage. In the case of muddy flow, farmers are able to affect the frequency[12] (e.g. by adopting the no tillage practice), while inhabitants might reduce the level of damage if any (e.g. by avoiding fitting out the basement).

Nevertheless, it is still possible, and useful, to consider the mutuality principle for risks that present some degree of correlation between them, but it should be associated to the other important principle in insurance, that means the transfer principle. We propose to discuss this combination in the case of muddy flow risks.

3.2 Implementing a compensation fund for the coverage of muddy flow damages

Compensation funds have been implemented since many years in some industrial sectors in order to compensate victims in the case of an incident due to the concerned activity. One of the oldest known funds is the one built by shipowners in the 1750's in order to insure themselves against the loss of their cargo (because of storms, pirats, ...). They gathered their risks, paid a regular contribution to the pool and, each time a cargo was lost or wrecked, its owner was compensated (at least partially) by the fund thanks to the premia initially collected.

The important and interesting points of the mutuality principle (applied in its simplest design by the shipowner) are twice. First, the premium paid by each contributor does not depend on his individual level of risk, but on the agregate risk (and his attitude towards risk), allowing individuals with high risks to be covered. Second, everyone within the pool has access to the same coverage characteristic, at a given paid premium. Hence this principle may induce efficient risk-spreading over the members of the pool.

These interesting arguments can be used in the muddy flow issue. Indeed, the ambient tax paid by the farmers does not depend on their individual risks, that is the risk relative to their own exploitation and to which people are exposed. The ambient tax depends on

[12] This does not exclude the fact that their risk-reducing activities may also affect the level of damage.

the agregate level of risk. If all risks of farmers in a same area (which has to be defined) are gathered within a pool, the ambient tax can be considered such as a premium paid by each farmer to the fund.

Nevertheless, there is a main difference between this system and the one related to the shipowners. In the case of muddy flows, farmers pay a contribution to the pool in order to make available some funds for compensating people that are not members of the fund (the inhabitants of the area). This is in line with the polluter-pay principle since individuals whose activities drive some negative externalities[13] should participate in the rehabilitation of the damaged sites and in the compensation programme even if they do not suffer directly from the damage[14]. Moreover, it is also close to the double dividend conjecture presented in the introduction: in our setting, the ambient tax is entirely redistributed to the agents of the area concerned by the compensation fund.

3.2.1 Aggregate risk and individual revelations

In the previous section, we suggested to mix the ambient tax scheme with a revelation process, through which the agents could avoid paying the ambient tax by revealing their good practices. Actually, this revelation process might weaken the mutuality principle because farmers would have the possibility to pay a contribution that depends on their individual characteristics. Indeed the ambient tax is lowered if the farmer shows that he has adopted some environmentally friendly practices. Nevertheless, we know that, besides the risk management itself, decisionmakers have also to cope with the social acceptability issue. Even if an instrument is efficient from an economic and environmental

[13] Such characteristics are also observed for other funds related to large risks. See for instance Schmitt and Spaeter (2005a, 2005b) for oil spill risks and Smets (1992) about compensation funds.

[14] This is not really the case with muddy flows since the patrimonial value of the land decreases as sediments are lessiviated. But even so, our arguments hold. Hence another important question that will arise in such a system deals with the oppportunity of the farmer to be also considered as a victim. This possibility, even if not unfair from a practical point of view, creates some informational issues (moral hazard, adverse selection) adressed by the agency theory in economics and is not considered in this paper.

point of view, its implementation could induce more costs than the created benefits if individuals are reluctant to use it or try to find some solutions in order to escape from its application. Thus, in the case of muddy flow and agricultural practices, a suitable economic instrument should involve a parameter that captures the acceptability dimension. In our model, this parameter may be the sensitivity of the ambient tax to the individual revelations: In the limit and unrealistic case of complete social acceptability of the ambient tax, individual revelations of the agents would not impact the level of the tax they pay. Only a decrease of the aggregate risk suffered by the whole area can make it decrease.

Now let us have a look on the behavior of the potential victims. From the economic literature on risk and insurance, we know that the optimal behavior for an insured agent is to decrease preventive and self-protective activities as insurance increases if his insurance premium is not linked to his preventive investments (Becker, 1968). This is especially the case if the insurer cannot observe the level of prevention or if audit of the agent's behaviour is too costly. Nevertheless, in the case of muddy flow, auto-protection consists in some measures that can be—at least partially—observed after a damage. Indeed forbidding the amenagement of the underground in a house could be one of these measures imposed by the insurer. It is also possible to give the agents incentives, such as for the farmers, to reveal their self-protective measures to the insurer before a damage occurs. In such a way, compensation of victims might depend upon their protection measures and this would give them incentives to make the adequate investment because of the threat of not being well indemnified[15]. The inhabitants should also contribute to the fund, but less than the farmers. Indeed, to be incentive the insurance service must be costly for them: And the insurance premia paid by the insured inhabitants could be added to the ambient tax, thereby increasing the available funds in the case of a muddy

[15] In the United States, insurance contracts for natural hazards are underwritten in two steps. First, a basic contract is signed with some limited coverage. Then the agent invests in preventive measures and brings this information to the insurer. In the second stage, the contract is renegociated and the insured person has access to better compensation conditions.

flow.

Finally, such a system that creates a link between indemnities and the *ex ante* behaviors of victims might also give rise to the emergence of a reputational effect for potential victims. They might suffer from bad reputation if they used to have large claims while the mean value of damages in the area, or in the village, is decreasing. Up to now, only farmers where considered as agents being able to suffer from bad reputation.

3.2.2 About the optimal scale

Until now, we discussed the limits and, above all, the advantages of implementing a compensation fund in a given area. A complementary question concerns the size of this area. It is important to realize that the mutuality principle must deal with approximately similar risks in order to be as efficient as possible (low risk-persons are not willing to gather their risks with high-risk persons). Thus it would be unrealistic to think about a national fund, supplied by different ambient taxes, evaluated in different regions. Even the region (Alsace, Haute Normandie, in the French sense) is not a good scale because of the diversity in the crops, but also in the climatic conditions and, above all, because of the pedological and agronomic characteristics of the soils. Hence the right scale might be the village, some area of the village, or two neighbouring villages, depending on their characteristics. For the particular case of the south of Alsace, the question of the scale of the area might find some insights in Auzet, Heitz, Armand, Guyonnet, and Moquet (2005). They worked on the natural catastrophes files of claimants and they obtained some useful data about the frequency of muddy flow, the level of damages, the nature of the damages, and others. Such files exist in France because a decree asserting the natural disaster state must be published to make funds specifically dedicated to natural catastrophes available from the insurers. Thus each village has to prepare documents about its damages for the local public authority. Coupled with informations on physical components of the muddy flow object (Armand, 2005), the work of Auzet et al. (2005) should make possible to build a map describing the vulnerable areas. The work in progress deals with risk perception and this map will be complemented by informations about how the inhabitants and the farmers perceive the risk in their area. This is especially important when focusing on the type of policy that should be implemented. Social acceptability, sensitivity to risks, level of knowledge, ..., are important factors in addition to pure economic ones.

4 Concluding discussion

All the arguments presented in this paper should induce at least one certainty: the ideal system that will give sufficient incentives to the farmers to change their practices and will induce more preventive behaviors from the citizens in the risky areas is not a system that uses only one economic tool, even if such a tool is efficient from the theoretical point of view (i.e. the ambient tax). We showed that several specificities interact in the muddy flow issue. This gives rise to some complexity but adds also some dimensions to the problem that can be exploited to solve it (at least partially).

For instance, farmers usually know their neighbours and communicate with them. From a theoretical point of view, this could lead to collusive behaviours, which fragilizes the equilibrium obtained without communication, and thus decreases the efficiency of the economic device. Nevertheless, the very fact that agents know each others in a given area might be used to create some reputational effects. Hence a given farmer might be willing to invest in new practices not only for direct financial reasons (due to subsidies for instance or taxes) but also because he might suffer from bad reputation effects or benefit from good reputation effects. This is particularly interesting if his behaviour affects the level of tax paid by the others, such as for the ambient tax. In the same spirit, an inhabitant who does not invest in prevention, while his neighbours adopt some safety measures in order to protect their house, may also suffer from bad reputation and even from a decrease in the compensation if a damage occurs.

The system that we discussed in the paper takes advantage of these effects. It combines the beneficial aspects of taxes (double dividend effect) and of individual revelations and it solves, at least partially, the issue of asymmetric informations by using an ambient tax rather than a pigouvien one.

Moreover, one originality of our approach deals with the fact that we do not separate the *ex ante* issue (prevention) from the *ex post* one (compensation). Taxes and premia collected *ex ante* are used for compensation if a disaster occurs. Lastly, the contracts are written in such a way that they give the agents incentives to invest in self-protective and preventive measures.

Some points remain questionnable.

In France, catastrophe insurance is compulsory, avoiding thus the Good Samaritan problem. Indeed the house-insurance premium of each homeowner is charged by a given percentage in order to finance natural hazard coverage. By this strategy, the government protects itself against the possibility that some people be not insured because they know that the State will compensate them in the case of a natural disaster. In the meantime, since the French compensation premium is only based on the monetary value of the agent's house (thus, indirectly on his income) and not on his own risk, it yields no incentives to be prudent. In doing so, it gives some importance to equity rather than to efficiency. In Germany, the system is radically different. Insurance is comprehensive and the premia depend entirely on the risk borne by the agent: the system is efficient from a theoretical point of view, but many people decide not to insure themselves. They usually underevaluate their risk and, as a direct consequence, refuse to pay the insurance premium asked by insurers. These pratical cases enhance the fact that the type of insurance, compulsory or comprehensive, has also an effect on the behaviour of the agents.

Closely related to this point is the question of what should be put in the insurance premium. An economist would say that the price of a good or a service must reflect its value. If there is some uncertainty of this value, because it depends on the realization of a random event, then the price should reflect the expected value of the good plus the risk it contains. In our setting, the service is an action of coverage conditioned by the level of a damage. The expected value of the damage should then be the important part of the premium. Nevertheless, this means also that high premia will be attached to high risks. Since the individual does not control natural hazards, it seems unfair to make depend the premium exclusively on the risk.

Actually, the premium should depend simultaneously on the individual risk and on the income of the agent. In the simplest case, it could be a weighted sum of both and the government could decide the weights to give to each component, depending on its goals. If the main objective is to create some strong incentives to invest in prevention, then a large weight should be given to efficiency, that means to the risk component in the premium. On the contrary, if the goal of the government is to permit each individual to have access to coverage whatever the area he is living in, then a large weight should be given to the level of income in the premium. A policy that mixes efficiency and equity will provide some fair weights for the risk and for the income argument.

Lastly, one should discuss about the possibility of implementing an audit policy. Indeed, we suggest in our setting that farmers could reveal their practices if doing so allows them to pay a lower (ambient) tax. Symmetrically, inhabitants that invest in preventive measures should be able to announce these investments to their insurer or to the Fund manager in order to benefit from a reduction in the insurance premium. Those informations could also be disclosed thanks to audit. By doing so, not the agent but the regulator will have an active role to play since he will have to seek the information. Such a system could be more costly, but it has the advantage to avoid some fraudulent declarations. The efficiency of a system with direct revelations compared to an audit policy will surely depend on the audit cost, but also on its ability in obtaining information and on the motivations of the agents to fight against muddy flows.

APPENDIX

Risk mutualization

Let $\widetilde{x}_i$ be the individual risk of Agent i with support $(x_{i1}, ..., x_{iS}; p_1, ..., p_S)$ where the second subscript of x denotes the state of nature (there are S possible states of nature in our example) and $p_j, j = 1...S$, is the probability of realization of state j. The variance of the risk $\widetilde{x}_i$ is denoted $Var(\widetilde{x}_i)$, with $0 < Var(\widetilde{x}_i) < +\infty$. Assume now that there are N agents in our group with independent individual risks: $\widetilde{x}_i, i = 1...N$, with same distribution and same expected value. Thus all individual risks have the same variance, which we denote V. The agregate risk of the pool is defined as $\widetilde{X} = \sum_{i=1}^{N} \widetilde{x}_i$. Finally, assume for the sake of simplicity, that each agent becomes a proportion $1/N$ of the agregate risk. The variance of the risk that they bear *in fine* is

$$\begin{aligned} Var(\frac{1}{N}\widetilde{X}) &= \frac{1}{N^2}Var(\widetilde{X}) \\ &= \frac{1}{N^2}Var(\sum_{i=1}^{N}\widetilde{x}_i) \\ &= \frac{1}{N^2}\sum_{i=1}^{N}Var(\widetilde{x}_i) \\ &= \frac{1}{N^2}.NVar(\widetilde{x}_i) \\ &= \frac{1}{N}.V \end{aligned}$$

The third equality comes from the indepency of the individual risks. Finally, the variance of $\widetilde{X}/N$ tends towards zero as N tends towards infinity.

References

Alpizar, F., T. Requate, and A. Schram (2004): "Collective versus Random Fining: An Experimental Study on Controlling Ambient Pollution," *Environmental and Resource Economics*, 29, 231–52.

Auzet, A.-V., Y. L. Bissonnais, and V. Souchère (2006): "Soil erosion in France," in *Soil erosion in Europe*, ed. by J.Boardman, and J.Poesen, pp. 369–383. Wiley.

Auzet, A.-V., J. Boiffin, F. Papy, J. Maucorps, and J.-F. Ouvry (1990): "An approach to the assessment of erosion forms, erosion risks on agricultural land in the Northern Paris Basin, France," in *Soil erosion on agricultural land*, ed. by J. Boardman, J. Dearing, and I. Foster, pp. 384–400. Wiley, Chichester.

Auzet, A.-V., C. Heitz, R. Armand, J. Guyonnet, and J.-S. Moquet (2005): "Les 'coulées de boue' dans le Bas-Rhin : analyse à partir des dossiers de demande de reconnaissance de lŠétat de catastrophe naturelle," Report, IMFS, ULP-CNRS Strasbourg.

Becker, G. S. (1968): "Crime and Punishment: An Economic Approach," *Journal of Political Economy*, 76, 169–217.

Boardman, J., and J. Poesen (2006): *Soil Erosion in Europe*. Wiley.

Braden, J. B., and K. Segerson (1993): "Information Problems in the Design of Nonpoint-Source Pollution Policy," in *Theory, Modeling, and Experience in the Management of Nonpoint-Source Pollution*, ed. by C. S. Russell, and J. F. Shogren, pp. 1–35. Boston: Kluwer Academic Publishers.

Camacho, E., and T. Requate (2004): "Collective and Random Fining versus Tax/Subsidy Schemes to Regulate Non-Point Pollution: An Experimental Study," mimeo, University of Kiel.

Cochard, F., M. Willinger, and A. Xepapadeas (2005): "Efficiency of Nonpoint Source Pollution Instruments: An Experimental Study," *Environmental and Resource Economics*, 30, 393–422.

Davis, D. D., and C. A. Holt (1993): *Experimental Economics*. Princeton University Press.

Fry, P. (2005): "Differing Views of Scientists and Farmers: Explaining Implementation problems and Sketching the Potential of Knowledge Exchange," COST 634 Meeting, Mont-Saint-Aignan, June 5-7, 2005, France.

Griffin, R. C., and D. W. Bromley (1982): "Agricultural Runoff as a Nonpoint Externality: A Theoretical Development," *American Journal of Agricultural Economics*, 64, 547–52.

HANSEN, L. G. (1998): “A Damage Based Tax Mechanism for Regulation of Non-Point Emissions,” *Environmental and Resource Economics*, 12, 99–112.

HAPPE, K., M. DAMGAARD, A. OSUCH, C. SATTLER, P. ZANDER, S. UTHES, J. SCHULER, AND A. PIORR (2006): “CAP-reform and the provision of non-commodity outputs in Brandenburg,” 55, 268–279.

HELMING, K., A.-V. AUZET, AND D. FAVIS-MORLOCK (2005): “Soil Erosion Patterns: Evolution, spatio-temporal dynamics and connectivity,” *Earth Surface Processes, Landforms*, 30, 131–132.

HOLMSTRÖM, B. (1982): “Moral Hazard in Teams,” *Bell Journal of Economics*, 13, 324–40.

HORAN, R. D., J. S. SHORTLE, AND D. G. ABLER (1998): “Ambient Taxes when Polluters have Multiple Choices,” *Journal of Environmental Economics and Management*, 36, 186–99.

KAGEL, J., AND A. E. ROTH (eds.) (1995): *Handbook of Experimental Economics.* Princeton: Princeton University Press.

KRITIKOS, A. (2004): “A Penalty System to Enforce Policy Measures under Incomplete Information,” *International Review of Law and Economics*, 24, 385–403.

KUHLMAN, T. (2006): “Estimating the Costs and Benefits of Soil Conservation,” COST 634 Meeting, WAgeningen, October 1-3, 2006, Holland.

MATHIEU, A., AND A. JOANNON (2005): “Combining Social Network and Technical Leeway in Farms Analysis to Reduce Runoff at Catchment’s Scale by Managing Crop Localisation,” COST 634 Meeting, Mont-Saint-Aignan, June 5-7, 2005, France.

NASH, J. (1950): “Equilibrium Points in N-Person Games,” *Proceedings of the National Academy of Sciences, U.S.A.*, 36, 48–9.

Poe, G. L., W. D. Schulze, K. Segerson, J. F. Suter, and C. A. Vossler (2004): "Exploring the Performance of Ambient-Based Policy Instrument When Non-Point Source Polluter Can Cooperate," *American Journal of Agricultural Economics*, 86, 1203–10.

Ribaudo, M. O., R. D. Horan, and M. E. Smith (1999): *Economics of Water Quality Protection from Nonpoint Sources: Theory and Practice*. Agricultural Economic Report No. (AER782).

Schmitt, A., and S. Spaeter (2005a): "Coverage of Large Risks: Theoretical Analysis and Application to Oil Spills," Mimeo BETA, Louis Pasteur University, Strasbourg.

——— (2005b): "Hedging Strategies and the Financing of the 1992 International Oil Pollution Compensation Fund," Working Paper nř 2005-12 BETA, Louis Pasteur University, Strasbourg.

Segerson, K. (1988): "Uncertainty and Incentives for Non-Point Source Pollution," *Journal of Environmental Economics and Management*, 15, 87–98.

Shogren, J. F. (2004): "Incentive Mechanism Testbeds: Discussion," *American Journal of Agricultural Economics*, 86, 1218–19.

Shortle, J. S., and D. G. Abler (1994): "Incentives for Nonpoint Pollution Control," in *Nonpoint Source Pollution Regulation: Issues and Analysis*, ed. by C. Dosi, and T. Tomasi, pp. 137–49. The Netherlands, Dordrecht: Kluwer Academic Publishers.

Shortle, J. S., and J. W. Dunn (1986): "The Relative Efficiency of Agricultural Source Water Pollution Control Policies," *American Journal of Environmental Economics*, 68, 668–77.

Smets, H. (1992): "L'indemnisation complète des victimes de la pollution accidentelle," *Risques*, 11, 49–71.

Spraggon, J. (2002): "Exogenous Targeting Instruments as a Solution to Group Moral Hazards," *Journal of Public Economics*, 84, 427–56.

——— (2004): "Exogenous Targeting Instruments with Heterogeneous Agents," *Journal of Environmental Economics and Management*, 48, 837–56.

Tomasi, T., K. Segerson, and J. B. Braden (1994): "Issues in the Design of Incentive Schemes for Nonpoint Source Pollution Control," in *Nonpoint Source Pollution Regulation: Issues and Analysis*, ed. by C. Dosi, and T. Tomasi, pp. 1–37. Dordrecht: Kluwer Academic Publishers.

Vossler, C. A., G. L. Poe, W. D. Schulze, and K. Segerson (2006): "Communication and Incentive Mechanisms Based on Group Performance: An Experimental Study of Nonpoint Pollution Control," *Economic Inquiry*, Forthcoming.

Xepapadeas, A. (1991): "Environmental Policy under Imperfect Information: Incentives and Moral Hazard," *Journal of Environmental Economics and Management*, 20, 113–26.

——— (1995): "Observability and Choice of Instrument Mix in the Control of Externalities," *Journal of Public Economics*, 56, 485–98.

Documents de travail du BETA

2000–**01** *Hétérogénéité de travailleurs, dualisme et salaire d'efficience.*
Francesco DE PALMA, janvier 2000.

2000–**02** *An Algebraic Index Theorem for Non–smooth Economies.*
Gaël GIRAUD, janvier 2000.

2000–**03** *Wage Indexation, Central Bank Independence and the Cost of Disinflation.*
Giuseppe DIANA, janvier 2000.

2000–**04** *Une analyse cognitive du concept de « vision entrepreneuriale ».*
Frédéric CRÉPLET, Babak MEHMANPAZIR, février 2000.

2000–**05** *Common knowledge and consensus with noisy communication.*
Frédéric KŒSSLER, mars 2000.

2000–**06** *Sunspots and Incomplete Markets with Real Assets.*
Nadjette LAGUÉCIR, avril 2000.

2000–**07** *Common Knowledge and Interactive Behaviors : A Survey.*
Frédéric KŒSSLER, mai 2000.

2000–**08** *Knowledge and Expertise : Toward a Cognitive and Organisational Duality of the Firm.*
Frédéric CRÉPLET, Olivier DUPOUËT, Francis KERN, Francis MUNIER, mai 2000.

2000–**09** *Tie–breaking Rules and Informational Cascades : A Note.*
Frédéric KŒSSLER, Anthony ZIEGELMEYER, juin 2000.

2000–**10** *SPQR : the Four Approaches to Origin–Destination Matrix Estimation for Consideration by the MYSTIC Research Consortium.*
Marc GAUDRY, juillet 2000.

2000–**11** *SNUS–2.5, a Multimoment Analysis of Road Demand, Accidents and their Severity in Germany, 1968–1989.*
Ulrich BLUM, Marc GAUDRY, juillet 2000.

2000–**12** *On the Inconsistency of the Ordinary Least Squares Estimator for Spatial Autoregressive Processes.*
Théophile AZOMAHOU, Agénor LAHATTE, septembre 2000.

2000–**13** *Turning Box–Cox including Quadratic Forms in Regression.*
Marc GAUDRY, Ulrich BLUM, Tran LIEM, septembre 2000.

2000–**14** *Pour une approche dialogique du rôle de l'entrepreneur/managerdans l'évolution des PME : l'ISO comme révélateur ...*
Frédéric CRÉPLET, Blandine LANOUX, septembre 2000.

2000–**15** *Diversity of innovative strategy as a source of technological performance.*
Patrick LLERENA, Vanessa OLTRA, octobre 2000.

2000–**16** *Can we consider the policy instruments as cyclical substitutes ?*
Sylvie DUCHASSAING, Laurent GAGNOL, décembre 2000.

2001–**01** *Economic growth and CO2 emissions : a nonparametric approach.*
Théophile AZOMAHOU, Phu NGUYEN VAN, janvier 2001.

2001–**02** *Distributions supporting the first–order approach to principal–agent problems.*
Sandrine SPÆTER, février 2001.

2001–**03** *Développement durable et Rapports Nord–Sud dans un Modèle à Générations Imbriquées : interroger le futur pour éclairer le présent.*
Alban VERCHÈRE, février 2001.

2001–**04** *Modeling Behavioral Heterogeneity in Demand Theory.*
Isabelle MARET, mars 2001.

2001–**05** *Efficient estimation of spatial autoregressive models.*
Théophile AZOMAHOU, mars 2001.

2001–**06** *Un modèle de stratégie individuelle de primo–insertion professionnelle.*
Guy TCHIBOZO, mars 2001.

2001–**07** *Endogenous Fluctuations and Public Services in a Simple OLG Economy.*
Thomas SEEGMULLER, avril 2001.

2001–**08** *Behavioral Heterogeneity in Large Economies.*
Gaël GIRAUD, Isabelle MARET, avril 2001.

2001–**09** *GMM Estimation of Lattice Models Using Panel Data : Application.*
Théophile AZOMAHOU, avril 2001.

2001–**10** *Dépendance spatiale sur données de panel : application à la relation Brevets–R&D au niveau régional.*
Jalal EL OUARDIGHI, avril 2001.

2001–**11** *Impact économique régional d'un pôle universitaire : application au cas strasbourgeois.*
Laurent GAGNOL, Jean–Alain HÉRAUD, mai 2001.

2001–**12** *Diversity of innovative strategy as a source of technological performance.*
Patrick LLERENA, Vanessa OLTRA, mai 2001.

2001–**13** *La capacité d'innovation dans les regions de l'Union Européenne.*
Jalal EL OUARDIGHI, juin 2001.

2001–**14** *Persuasion Games with Higher Order Uncertainty.*
Frédéric KŒSSLER, juin 2001.

2001–**15** *Analyse empirique des fonctions de production de Bosnie–Herzégovine sur la période 1952–1989.*
Rabija SOMUN, juillet 2001.

2001–**16** *The Performance of German Firms in the Business–Related Service Sectors : a Dynamic Analysis.*
Phu NGUYEN VAN, Ulrich KAISER, François LAISNEY, juillet 2001.

2001–**17** *Why Central Bank Independence is high and Wage indexation is low.*
Giuseppe DIANA, septembre 2001.

2001–**18** *Le mélange des ethnies dans les PME camerounaises : l'émergence d'un modèle d'organisation du travail.*
Raphaël NKAKLEU, octobre 2001.

2001–**19** *Les déterminants de la GRH des PME camerounaises.*
Raphaël NK AKLEU, octobre 2001.

2001–**20** *Profils d'identité des dirigeants et stratégies de financement dans les PME camerounaises.*
Raphaël NKAKLEU, octobre 2001.

2001–**21** Concurrence Imparfaite, Variabilité du Taux de Marge et Fluctuations Endogènes.
Thomas SEEGMULLER, novembre 2001.

2001–**22** *Determinants of Environmental and Economic Performance of Firms : An Empirical Analysis of the European Paper Industry.*
Théophile AZOMAHOU, Phu NGUYEN VAN et Marcus WAGNER, novembre 2001.

2001–**23** *The policy mix in a monetary union under alternative policy institutions and asymmetries.*
Laurent GAGNOL et Moïse SIDIROPOULOS, décembre 2001.

2001–**24** *Restrictions on the Autoregressive Parameters of Share Systems with Spatial Dependence.*
Agénor LAHATTE, décembre 2001.

2002–**01** *Strategic Knowledge Sharing in Bayesian Games : A General Model.*
Frédéric KŒSSLER, janvier 2002.

2002–**02** *Strategic Knowledge Sharing in Bayesian Games : Applications.*
Frédéric KŒSSLER, janvier 2002.

2002–**03** *Partial Certifiability and Information Precision in a Cournot Game.*
Frédéric KŒSSLER, janvier 2002.

2002–**04** *Behavioral Heterogeneity in Large Economies.*
Gaël GIRAUD, Isabelle MARET, janvier 2002.
(Version remaniée du Document de Travail n°2001–**08**, avril 2001).

2002–**05** *Modeling Behavioral Heterogeneity in Demand Theory.*
Isabelle MARET, janvier 2002.
(Version remaniée du Document de Travail n°2001–**04**, mars 2001).

2002–**06** *Déforestation, croissance économique et population : une étude sur données de panel.*
Phu NGUYEN VAN, Théophile AZOMAHOU, janvier 2002.

2002–**07** *Theories of behavior in principal–agent relationships with hidden action.*
Claudia KESER, Marc WILLINGER, janvier 2002.

2002–**08** *Principe de précaution et comportements préventifs des firmes face aux risques environnementaux.*
Sandrine SPÆTER, janvier 2002.

2002–**09** *Endogenous Population and Environmental Quality.*
Phu NGUYEN VAN, janvier 2002.

2002–**10** *Dualité cognitive et organisationnelle de la firme au travers du concept de communauté.*
Frédéric CRÉPLET, Olivier DUPOUËT, Francis KERN, Francis MUNIER, février 2002.

2002–**11** *Comment évaluer l'amélioration du bien–être individuel issue d'une modification de la qualité du service d'élimination des déchets ménagers ?*
Valentine HEINTZ, février 2002.

2002–**12** *The Favorite–Longshot Bias in Sequential Parimutuel Betting with Non–Expected Utility Players.*
Frédéric KŒSSLER, Anthony ZIEGELMEYER, Marie–Hélène BROIHANNE, février 2002.

2002–**13** *La sensibilité aux conditions initiales dans les processus individuels de primo–insertion professionnelle : critère et enjeux.*
Guy TCHIBOZO, février 2002.

2002–**14** *Improving the Prevention of Environmental Risks with Convertible Bonds.*
André SCHMITT, Sandrine SPÆTER, mai 2002.

2002–**15** *L'altruisme intergénérationnel comme fondement commun de la courbe environnementale* ***à la*** *Kuznets et du développement durable.*
Alban VERCHÈRE, mai 2002.

2002–**16** *Aléa moral et politiques d'audit optimales dans le cadre de la pollution d'origine agricole de l'eau.*
Sandrine SPÆTER, Alban VERCHÈRE, juin 2002.

2002–**17** *Parimutuel Betting under Asymmetric Information.*
Frédéric KŒSSLER, Anthony ZIEGELMEYER, juin 2002.

2002–**18** *Pollution as a source of endogenous fluctuations and periodic welfare inequality in OLG economies.*
Thomas SEEGMULLER, Alban VERCHÈRE, juin 2002.

2002–**19** *La demande de grosses coupures et l'économie souterraine.*
Gilbert KŒNIG, juillet 2002.

2002–**20** *Efficiency of Nonpoint Source Pollution Instruments with Externality Among Polluters : An Experimental Study.*
François COCHARD, Marc WILLINGER, Anastasios XEPAPADEAS, juillet 2002.

2002–**21** *Taille optimale dans l'industrie du séchage du bois et avantage compétitif du bois–énergie : une modélisation microéconomique.*
Alexandre SOKIC, octobre 2002.

2002–**22** *Modelling Behavioral Heterogeneity.*
Gaël GIRAUD, Isabelle MARET, novembre 2002.

2002–**23** *Le changement organisationnel en PME : quels acteurs pour quels apprentissages ?*
Blandine LANOUX, novembre 2002.

2002–**24** *TECHNOLOGY POLICY AND COOPERATION : An analytical framework for a paradigmatic approach.*
Patrick LLERENA, Mireille MATT, novembre 2002.

2003–**01** *Peut–on parler de délégation dans les PME camerounaises ?*
Raphaël NKAKLEU, mars 2003.

2003–**02** *L'identité organisationnelle et création du capital social : la tontine d'entreprise comme facteur déclenchant dans le contexte africain.*
Raphaël NKAKLEU, avril 2003.

2003–**03** *A semiparametric analysis of determinants of protected area.*
Phu NGUYEN VAN, avril 2003.

2003–**04** *Strategic Market Games with a Finite Horizon and Incomplete Markets.*
Gaël GIRAUD et Sonia WEYERS, avril 2003.

2003–**05** *Exact Homothetic or Cobb–Douglas Behavior Through Aggregation.*
Gaël GIRAUD et John K.–H. QUAH, juin 2003.

2003–**06** *Relativité de la satisfaction dans la vie : une étude sur données de panel.*
Théophile AZOMAHOU, Phu NGUYEN VAN, Thi Kim Cuong PHAM, juin 2003.

2003–**07** *A model of the anchoring effect in dichotomous choice valuation with follow–up.*
Sandra LECHNER, Anne ROZAN, François LAISNEY, juillet 2003.

2003–**08** *Central Bank Independence, Speed of Disinflation and the Sacrifice Ratio.*
Giuseppe DIANA, Moïse SIDIROPOULOS, juillet 2003.

2003–**09** *Patents versus ex–post rewards : a new look.*
Julien PÉNIN, juillet 2003.

2003–**10** *Endogenous Spillovers under Cournot Rivalry and Co–opetitive Behaviors.*
Isabelle MARET, août 2003.

2003–**11** *Les propriétés incitatives de l'effet Saint Matthieu dans la compétition académique.*
Nicolas CARAYOL, septembre 2003.

2003–**12** *The 'probleme of problem choice' : A model of sequential knowledge production within scientific communities.*
Nicolas CARAYOL, Jean–Michel DALLE, septembre 2003.

2003–**13** *Distribution Dynamics of CO_2 Emissions.*
Phu NGUYEN VAN, décembre 2003.

2004–**01** *Utilité relative, politique publique et croissance économique.*
Thi Kim Cuong PHAM, janvier 2004.

2004–**02** *Le management des grands projets de haute technologie vu au travers de la coordination des compétences.*
Christophe BELLEVAL, janvier 2004.

2004–**03** *Pour une approche dialogique du rôle de l'entrepreneur/manager dans l'évolution des PME : l'ISO comme révélateur …*
Frédéric CRÉPLET, Blandine LANOUX, février 2004.

2004–**04** *Consistent Collusion–Proofness and Correlation in Exchange Economies.*
Gaël GIRAUD, Céline ROCHON, février 2004.

2004–**05** *Generic Efficiency and Collusion–Proofness in Exchange Economies.*
Gaël GIRAUD, Céline ROCHON, février 2004.

2004–**06** *Dualité cognitive et organisationnelle de la firme fondée sur les interactions entre les communautés épistémiques et les communautés de pratique..*
Frédéric CRÉPLET, Olivier DUPOUËT, Francis KERN, Francis MUNIER, février 2004.

2004–**07** *Les Portails d'entreprise : une réponse aux dimensions de l'entreprise « processeur de connaissances ».*
Frédéric CRÉPLET, février 2004.

2004–**08** *Cumulative Causation and Evolutionary Micro–Founded Technical Change : A Growth Model with Integrated Economies.*
Patrick LLERENA, André LORENTZ, février 2004.

2004–**09** *Les CIFRE : un outil de médiation entre les laboratoires de recherche universitaire et les entreprises.*
Rachel LÉVY, avril 2004.

2004–**10** *On Taxation Pass–Through for a Monopoly Firm.*
Rabah AMIR, Isabelle MARET, Michael TROGE, mai 2004.

2004–**11** *Wealth distribution, endogenous fiscal policy and growth : status–seeking implications.*
Thi Kim Cuong PHAM, juin 2004.

2004–**12** *Semiparametric Analysis of the Regional Convergence Process.*
Théophile AZOMAHOU, Jalal EL OUARDIGHI, Phu NGUYEN VAN, Thi Kim Cuong PHAM, Juillet 2004.

2004–**13** *Les hypothèses de rationalité de l'économie évolutionniste.*
Morad DIANI, septembre 2004.

2004–**14** *Insurance and Financial Hedging of Oil Pollution Risks.*
André SCHMITT, Sandrine SPAETER, septembre 2004.

2004–**15** *Altruisme intergénérationnel, développement durable et équité intergénérationnelle en présence d'agents hétérogènes.*
Alban VERCHÈRE, octobre 2004.

2004–**16** *Du paradoxe libéral–parétien à un concept de métaclassement des préférences.*
Herrade IGERSHEIM, novembre 2004.

2004–**17** *Why do Academic Scientists Engage in Interdisciplinary Research ?*
Nicolas CARAYOL, Thuc Uyen NGUYEN THI, décembre 2004.

2005–**01** *Les collaborations Université Entreprises dans une perspective organisationnelle et cognitive.*
Frédéric CRÉPLET, Francis KERN, Véronique SCHAEFFER, janvier 2005.

2005–**02** *The Exact Insensitivity of Market Budget Shares and the 'Balancing Effect'.*
Gaël GIRAUD, Isabelle MARET, janvier 2005.

2005–**03** *Les modèles de type Mundell–Fleming revisités.*
Gilbert KOENIG, janvier 2005.

2005–**04** *L'État et la cellule familiale sont–ils substituables dans la prise en charge du chômage en Europe ? Une comparaison basée sur le panel européen.*
Olivia ECKERT–JAFFE, Isabelle TERRAZ, mars 2005.

2005–**05** *Environment in an Overlapping Generations Economy with Endogenous Labor Supply : a Dynamic Analysis.*
Thomas SEEGMULLER, Alban VERCHÈRE, mars 2005.

2005–**06** *Is Monetary Union Necessarily Counterproductive ?*
Giuseppe DIANA, Blandine ZIMMER, mars 2005.

2005–**07** *Factors Affecting University–Industry R&D Collaboration : The importance of screening and signalling.*
Roberto FONTANA, Aldo GEUNA, Mireille MATT, avril 2005.

2005–**08** *Madison–Strasbourg, une analyse comparative de l'enseignement supérieur et de la recherche en France et aux États–Unis à travers l'exemple de deux campus.*
Laurent BUISSON, mai 2005.

2005–**09** *Coordination des négociations salariales en UEM : un rôle majeur pour la BCE.*
Blandine ZIMMER, mai 2005.

2005–**10** *Open knowledge disclosure, incomplete information and collective innovations.*
Julien PÉNIN, mai 2005.

2005–**11** *Science–Technology–Industry Links and the 'European Paradox' : Some Notes on the Dynamics of Scientific and Technological Research in Europe.*
Giovanni DOSI, Patrick LLERENA, Mauro SYLOS LABINI, juillet 2005.

2005–**12** *Hedging Strategies and the Financing of the 1992 International Oil Pollution Compensation Fund.*
André SCHMITT, Sandrine SPAETER, novembre 2005.

2005–**13** *Faire émerger la coopération internationale : une approche expérimentale comparée du bilatéralisme et du multilatéralisme*.
Stéphane BERTRAND, Kene BOUN MY, Alban VERCHÈRE, novembre 2005.

2005–**14** *Segregation in Networks.*
Giorgio FAGIOLO, Marco VALENTE, Nicolaas J. VRIEND, décembre 2005.

2006–**01** *Demand and Technology Determinants of Structural Change and Tertiarisation : An Input–Output Structural Decomposition Analysis for four OECD Countries.*
Maria SAVONA, André LORENTZ, janvier 2006.

2006–**02** *A strategic model of complex networks formation.*
Nicolas CARAYOL, Pascale ROUX, janvier 2006.

2006–**03** *Coordination failures in network formation.*
Nicolas CARAYOL, Pascale ROUX, Murat YILDIZOGLU, janvier 2006.

2006–**04** *Real Options Theory for Lawmaking.*
Marie OBIDZINSKI, Bruno DEFFAINS, août 2006.

2006–**05** *Ressources, compétences et stratégie de la firme : Une discussion de l'opposition entre la vision Porterienne et la vision fondée sur les compétences.*
Fernand AMESSE, Arman AVADIKYAN, Patrick COHENDET, janvier 2006.

2006–**06** *Knowledge Integration and Network Formation.*
Müge OZMAN, janvier 2006.

2006–**07** *Networks and Innovation : A Survey of Empirical Literature.*
Müge OZMAN, février 2006.

2006–**08** *A.K. Sen et J.E. Roemer : une même approche de la responsabilité ?*
Herrade IGERSHEIM, mars 2006.

2006–**09** *Efficiency and coordination of fiscal policy in open economies.*
Gilbert KOENIG, Irem ZEYNELOGLU, avril 2006.

2006–**10** *Partial Likelihood Estimation of a Cox Model With Random Effects : an EM Algorithm Based on Penalized Likelihood.*
Guillaume HORNY, avril 2006.

2006–**11** *Uncertainty of Law and the Legal Process.*
Giuseppe DARI–MATTIACCI, Bruno DEFFAINS, avril 2006.

2006–**12** *Customary versus Technological Advancement Tests.*
Bruno DEFFAINS, Dominique DEMOUGIN, avril 2006.

2006–**13** *Institutional Competition, Political Process and Holdup.*
Bruno DEFFAINS, Dominique DEMOUGIN, avril 2006.

2006–**14** *How does leadership support the activity of communities of practice ?*
Paul MULLER, avril 2006.

2006–**15** *Do academic laboratories correspond to scientific communities ? Evidence from a large European university.*
Rachel LÉVY, Paul MULLER, mai 2006.

2006–**16** *Knowledge flows and the geography of networks. A strategic model of small worlds formation.*
Nicolas CARAYOL, Pascale ROUX, mai 2006.

2006–**17** *A Further Look into the Demography–based GDP Forecasting Method.*
Tapas K. MISHRA, juin 2006.

2006–**18** *A regional typology of innovation capacities in new member states and candidate countries.*
Emmanuel MULLER, Arlette JAPPE, Jean–Alain HÉRAUD, Andrea ZENKER, juillet 2006.

2006–**19** *Convergence des contributions aux inégalités de richesse dans le développement des pays européens.*
Jalal EL OUARDIGHI, Rabiji SOMUN–KAPETANOVIC, septembre 2006.

2006–**20** *Channel Performance and Incentives for Retail Cost Misrepresentation.*
Rabah AMIR, Thierry LEIBER, Isabelle MARET, septembre 2006.

2006–**21** *Entrepreneurship in biotechnology : The case of four start–ups in the Upper–Rhine Biovalley.*
Antoine BURETH, Julien PÉNIN, Sandrine WOLFF, septembre 2006.

2006–**22** *Does Model Uncertainty Lead to Less Central Bank Transparency ?*
Li QIN, Elefterios SPYROMITROS, Moïse SIDIROPOULOS, octobre 2006.

2006–**23** Enveloppe *Soleau et droit de possession antérieure : Définition et analyse économique.*
Julien PÉNIN, octobre 2006.

2006–**24** *Le territoire français en tant que Système Régional d'Innovation.*
Rachel LEVY, Raymond WOESSNER, octobre 2006.

2006–**25** *Fiscal Policy in a Monetary Union Under Alternative Labour–Market Structures.*
Moïse SIDIROPOULOS, Eleftherios SPYROMITROS, octobre 2006.

2006–**26** *Robust Control and Monetary Policy Delegation.*
Giuseppe DIANA, Moïse SIDIROPOULOS, octobre 2006.

2006–**27** *A study of science–industry collaborative patterns in a large european university.*
Rachel LEVY, Pascale ROUX, Sandrine WOLFF, octobre 2006.

2006–**28** *Option chain and change management : a structural equation application.*
Thierry BURGER–HELMCHEN, octobre 2006.

2006–**29** *Prevention and Compensation of Muddy Flows : Some Economic Insights.*
Sandrine SPAETER, François COCHARD, Anne ROZAN, octobre 2006.

La présente liste ne comprend que les Documents de Travail publiés à partir du 1er janvier 2000. La liste complète peut être donnée sur demande.
This list contains the Working Paper writen after January 2000, 1rst. The complet list is available upon request.