ECOLE POLYTECHNIQUE
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

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June 2005

Cahier n° 2005-020

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Résumé: Cet article confronte les interprétations proposées pour le principe de précaution qui viennent de deux horizons différents : les théories économiques du risque qui s'inscrivent dans un cadre bayésien et les repères heuristiques de la doctrine validée par les institutions européennes et françaises. Les traits communs sont mis en évidence, mais aussi d'importantes différences quant aux concepts et aux contextes d'application. Malgré ces différences, l'analyse économique propose des éclairages utiles sur plusieurs questions controversées soulevées par la mise en œuvre du principe de précaution comme norme sociale. Cela concerne par exemple la réversibilité des mesures de précaution, la question de l'application directe du principe à toute personne ou aux seules autorités publiques et le problème de l'imputation de la charge de l'instruction scientifique des hypothèses de risque.

Abstract: This paper matches interpretations of the precautionary principle coming from two horizons: economic theory of risk framed in a Bayesian framework, and social heuristic concepts validated by public European and domestic institutions. Although they share some common features, it is shown that concepts and scopes differ a lot. In spite of this difference, analytical economics provide useful insights on key controversial questions for the implementation of this principle as a social norm. Examples concern the reversibility of precautionary measures, the issue of direct application to all individual agents versus reserved application to public bodies, and the burden of bringing appropriate scientific inputs.

Mots clés : Principe de précaution, Gestion des risques, Incertitude, Environnement, Santé

Key Words : Precautionary principle, Risk management, Uncertainty, Environment, Health

Classification JEL: D81, I18, K42

1. Introduction

Within about a decade, the precautionary principle has become a new international standard for public policies when potential collective hazards are at stake, i.e hazards the very existence of which has not been either formally established or refuted by sound scientific approaches. Such hazards are just asserted as potential, with various degree of plausibility, under existing scientific knowledge. Various fields are affected: environmental issues, food safety, public health and bio-ethics. In spite of a broad acknowledgement in Europe, there are still many controversies upon its meaning, scope, legal status and value for decision-making. Disputes have arisen in international arenas such as WTO about the extent to which the 'precautionary principle' (written PP in the following) or just a 'precautionary approach' could legitimately be taken into account by governments for deciding trade-restricting measures. At a country-level, different stakeholders try to impose their own views regarding modern technological developments like GMOs by putting those views as a direct expression of what the PP is supposed to require. This leads to a medley of national policies, with different requirements and priorities.

For some eco-activists[1], the PP comes to what has been called an 'abstaining rule' (Godard [1997b]), often defended on the basis of the work of German philosopher Hans Jonas [1984] on the 'Imperative of Responsibility' of present generations regarding the preservation of the ultimate possibility to maintain a truly human life on planet Earth. Under its lay version, this 'abstaining rule' would command that defenders of a potentially hazardous activity or technology bring the scientific proof of harmlessness before the latter can be authorised. Flawed by logical inconsistency – with a science permanently in progress but never completed, there is a logical impossibility of proving "there are and will be no harmful effects"- this rule also imposes a 'zero risk' norm for potential risks. The moral philosophy of Jonas explicitly targeted potentially apocalyptic global events only, but was not supposed to be appropriate to more ordinary human activities that have potentially serious, but non-apocalyptic impacts on the environment or human health (Godard et al., [2002]). Due to scarcity of public resources and the pressure of other needs, the 'abstaining rule' would not only be very costly in welfare terms but unfeasible. Zero risk in one potential case would mean more risk in other cases. What would happen in practice would be an arbitrarily selective use of the rule, implying high direct or opportunity costs. Meanwhile huge sources of risks that are perfectly known (tobacco, alcohol, car crashes, …) will still be tolerated, not succeeding in attracting sufficient attention and resources to be reduced at a level more in line with welfare criteria.

For other parties, in business or medical circles for instance, the PP tends to be perceived as an irrational, counter-productive norm. It is blamed for not strictly referring to scientific analysis and evidence, and for putting too much responsibility on the shoulders of some categories of agents who have to take decisions and initiatives (entrepreneurs, physicians, civil servants, researchers…). The PP would ultimately cause severe damage to industrial innovation and progress in health care. For some specialists of public health policies (Setbon [1999]), the PP would even have a net negative score as a standard for prevention policies by comparison with usual prevention policies based on sound science (risk analysis and statistics used in epidemiology): early but badly informed action would have to target a

[1] See the political landscape sketched by O'Riordan and Jordan [1995].

wide scope of potential factors, imposing costs and changes of practices to many people without having any assurance to obtain practical benefits from it; such actions will be seen as hardly legitimate by all the affected agents and those responsible of its implementation; policy measures would be poorly implemented, contributing to confusion and distrust among lay people regarding the running of public institutions. Thus, for these parties, the emergence of the PP brings an unjustifiable end to science-based, rational public action.

Fortunately, the PP as defined by positive law is definitely not either a general 'abstaining rule' or a rule imposing a rupture with reasonable foundations of public action. It obliges authorities to take an early account of potential hazards, but it does not say that abstaining should prevail every time a hazard cannot be demonstrated not to exist. Absolute avoidance of risk may be an appropriate attitude in a few cases but does not stand as a general norm. For instance, a French environmental law adopted in 1995 (Law 95-101), echoing international law formulations in a balanced statement, defined the PP in the following terms:

> "*the lack of certainty, under the present state of scientific and technological knowledge, should not lead to postpone effective and proportionate measures aimed at preventing threats of serious and*[2] *irreversible damages to the environment at an acceptable economic cost*".

Two important ideas in this definition are the 'acceptable economic cost of prevention' and the 'proportionality of prevention efforts'. This is where economic thinking and assessment can and should legitimately fit in the landscape.

Risk and uncertainty are not new issues for economic thinking. Without going back as far as early contributions of Knight or Keynes in the twenties, theoretical insights and conceptual breakthroughs produced during the last three decades have been important. Unfortunately they have not been equally incorporated by practical policy-making in the fields of hazard prevention and environmental-related risk management. To some extent the PP is an innovation in the policy field that echoes economic concepts and insights already established for a long while. So trying to isolate what is really new and different with the PP for economists is not an easy task. For instance, links between irreversibility, risk and prospects of increasing information have been demonstrated by Henry [1974a and b] and Arrow et Fischer [1974] more than twenty-five years ago; their work led to the concept of (quasi) option value attached to reversible actions even for risk-neutral agents, when progress of information is exogenous. This breakthrough of the 'irreversibility effect' triggered an important research program having ramifications into several economic specialties. For instance it has been generalized and incorporated in investment theory by Dixit and Pindyck [1994], in such a way that most investors should now be prepared to host the basic concepts and issues of precautionary strategies. More recently Gollier, Jullien and Treich [2000] made a significant contribution by isolating in a Bayesian framework what they call a 'precautionary effect' related to the concept of prudence in savings theory and distinct from the 'irreversibility effect'.

At the same time, as a new social norm, the PP cannot be reduced to an exercise in applied economics or a synthesis of all recent theoretical achievements in economics. It has a consistence of its own as a cornerstone of several policy issues. For instance, the PP is a

[2] In the equivalent formula chosen in the 1992 Rio Declaration at the Earth Summit, it was written "*serious or irreversible damage…*".

benchmark for managing provisional measures while waiting for an expected resolution of scientific uncertainty, but it cannot be reduced to this, as it is also used to justify long run action against a class of hazards. As a legal norm, the PP is linked to a moral and political background, but it is not a moral concept. The choice of procedures to put the principle into practice will have feed back effects on the content of the concept. There are questions about the respective role given to expert assessment and public debate to enlighten the content of 'proportionate and economically acceptable' measures. An unresolved law issue is related to the extent to which the PP directly creates new legal obligations not only for public bodies and decision-makers, but also for economic agents and individuals.

The purpose of this paper is not to consider all these questions but to gain insights by matching formal economic and decision theory and reasoned social heuristic concepts that are presently validated as a doctrine by institutional bodies in Europe. Such heuristic benchmarks jointly incorporate elements coming from the social and political debate and inputs from academic work. Two directions are explored: (1) what are the conceptual differences between the PP as a social norm and economic interpretations proposed for this principle? (2) Which proposals of heuristic rules can be supported by current economic concepts and insights in the debates that are raised by the implementation of the PP? Matching theory and socially built heuristic rules does not confuse social norms with theoretic economic concepts but intend to make a profitable use of relevant results in policy contexts. I chose the article of Gollier *et al.* [2000] as the main representative of the mainstream theoretical economic approach of precaution[3]. In the following ^{S}PP stands for the social norm of the PP, while ^{B}PP stands for the Bayesian model of Gollier et al.

2. Basic similarities and differences

2.1. Similarities

In the following section, I am going to insist upon differences between ^{S}PP and ^{B}PP. But, before all, I have to stress that the two concepts have some features in common. Some specific points will be noticed in the course of analysis. Meanwhile it is wise to explicit three basic common features:

- The PP applies to scientifically uncertain hazards and dangers, not just random events. This distinction is important: with random events, we do not know which event will happen at a point of the space-time framework; with uncertain hazards, we do not know causal mechanisms and laws of process to such an extent that we do not know if those hazards do exist. Improving knowledge of the randomness of a given class of events depends on repeated experience and observation, but improving knowledge of uncertain hazards mostly depends on scientific research activities combining both empirical and theoretical work. A distinctive and important feature for the PP is that where there is scientific uncertainty, there is a prospect that knowledge of potential hazards may develop in the future as a result of scientific research.

[3] This does not mean that I deny the existence of a vigorous stream of economic research devoted to non-Bayesian approaches of uncertainty. But until recently this stream did not explicitly contribute to the debate on the precautionary principle. See for instance the review by Starmer [2000] or Henry and Henry [2002].

- The decision problem is generally framed as a dynamic, sequential one, which gives primordial importance to the issue of optimal timing of prevention (when to begin prevention of potential hazards? How to allocate resources for prevention at different time periods?) in a context that combines a prospect of scientific learning and multi-source threats of irreversibility (physical phenomena in the environment, damage to humans, economic investment with sunk costs, inertia of social rules);
- the endogenous nature of potential hazards of concern; according to human action in periods *1, 2,…* the level of potential hazards for period *n, n+1,…* is mitigated or amplified.

2.2. Divergences on the content of precaution

The ^{S}PP is grounded on the distinction between when the existence of a given hazard is ascertained, although its achievement may be random and described by objective probabilities (case of floods), and when it is still not well-established by science or experience, being just a non-rejected hypothesis or theory. Before the ^{S}PP became an admitted norm, prevention for environmental matters could only be justified if the existence of the hazard had been proved. Mere assumptions, or allegations by some agents (local populations, NGOs) that negative environmental impacts would occur as a consequence of some activity or technology could not trigger public preventive policies. The first consequence of the adoption of the ^{S}PP as a social, ethical, political and legal norm is to extend the circumstances under which authorities could or should take preventive measures, whatever their content. Most definitions of the ^{S}PP in international and domestic law express this idea that "*the lack of certainty, under present state of knowledge, should not lead to postpone prevention measures*". With the ^{S}PP it is no longer expected from scientists and NGOs to bring the proof of the existence of damage for authorities to accept to deal with it. This is why the ^{S}PP is supposed to respond to situations of uncertainty and not of risks, if we take these terms in the sense defined by Knight [1921]. Precaution is a response to uncertain hazard the same way as science-rooted prevention is a response to known risks of adverse effects.

Here, uncertainty refers to specific contexts: either an impossibility to set a rational distribution of probabilities exemplified by unique events, or an incomplete appraisal of possible states of the world. The latter includes the possibility of surprises and competing visions of the world that lead to mutually incompatible alternate sets of states. Thus uncertain hazards, i.e. hazards the existence of which has been neither demonstrated nor refuted by science, are clearly distinguished from randomly distributed hazards. Precaution relates to the former and prevention to the latter.

The theoretical approach developed by Gollier *et al.* [2000] is quite different. It is framed within a Bayesian approach of risks, taking subjective probabilities as a substitute for objective ones. The 'precautionary effect' is related to (a) the prospect of an improvement of the acuteness of information, due to scientific progress, and (b) a specific constraint on the shape of the Von Neumann-Morgenstern utility function of agents: the latter have to be 'prudent' in the sense of Kimball [1990]. A prudent agent increases its immediate savings when risk affecting his future income increases. Here an increasing uncertainty is seen as an increasing dispersion of outcomes around the mean value. The statement that the prospect of better information increases the uncertainty perceived ex ante sets a link between both factors.

Within this framework, ^{B}PP is defined as 'more prevention in the short run' when there is a prospect of better information in the future, compared with unchanged information, even if no irreversibility is at stake. This net 'precautionary effect' takes place in spite of the fact that delaying prevention would avoid immediate costs and allow a better-adjusted action in the future too. Both effects would produce an incremental wealth effect that could justify less prevention on the whole than when there is no prospect of improved information. But ^{B}PP stands when this wealth effect is more than counterbalanced by the negative impact of an increased *ex ante* uncertainty on utility.

With this background, matching ^{S}PP with ^{B}PP demonstrates four important differences.

(1) ^{B}PP does not distinguish between risk and uncertainty, but rests on Savage's argument [1954] that all probabilities are subjective since they imply some confidence level on the information given by others (scientists, experts) or directly obtained by experience. So the issue of having the existence of a hazard to be scientifically proven or not proven completely disappears with ^{B}PP. The quest of scientific proofs is substituted by the beliefs of decision-makers related to the existence and frequency of some hazards on the basis of their own prior subjective probability distribution. Scientific progress is relevant to the extent that it contributes to the regular process of revision of beliefs. Formally, ignorance, intrinsic scientific indeterminacy, resolvable scientific uncertainty, polarised scientific controversies around conflicting theories in progress, contingent and conventional aspects of any applied knowledge, pure randomness of events are all confused in one same structure, whatever the relevance of their distinction for practical problem-solving.

The main message that emerged from the debate on the ^{S}PP (Kourilsky and Viney [2000])[4], led to a distinction between precaution and prevention: precaution concerns potential or hypothetical hazards (uncertainty) whereas prevention deals with known and recognised risks. This distinction cannot be understood within the ^{B}PP model. Instead ^{B}PP proposes another dichotomy: risky context with improving information, versus those with unchanged information. To this regard the ^{B}PP is seen just as a paradigm for managing how to wait for better information from scientific development[5].

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[4] In this official report to the French Prime Minister, the authors state: "*The distinction between potential hazards and certified hazards is the foundation of the parallel distinction between precaution and prevention. Precaution relates to potential hazards and prevention to certified ones. (…). People often think that potential hazards have a low probability; the latter are unconsciously assimilated to certified risks the probability of which is all the more low since they are under control. This is twice wrong. Firstly probabilities at stake do not have the same nature (with precaution, we deal with the probability that a given hypothesis is right; with prevention, the hazard is established, and relates to the probability of an accident). Moreover and most of all , potential hazards, although hypothetical, may have a high probability of occurrence.*" ("*La distinction entre risque potentiel et risque avéré fonde la distinction parallèle entre précaution et prévention. La précaution est relative à des risques potentiels et la prévention à des risques avérés. (…) On pense souvent que les risques potentiels sont peu probables et on les assimile inconsciemment à des risques avérés dont la probabilité est d'autant plus faible qu'ils sont bien maîtrisés. Ceci est doublement inexact. D'abord les probabilités ne sont pas de même nature (dans le cas de la précaution, il s'agit de la probabilité que l'hypothèse soit exacte ; dans le cas de la prévention, la dangerosité est établie et il s'agit de la probabilité de l'accident). En outre, et surtout, les risques potentiels, en dépit de leur caractère hypothétique, peuvent avoir une probabilité de réalisation élevée"* (Kourilsky and Viney [2000], p. 18).

[5] To stress the specificity of precaution according to this theory, Treich [1997] states: "*While prevention aims at managing risks, precaution aims at managing the wait for information*". ("*Alors que la prévention vise à gérer les risques, la précaution vise à gérer l'attente d'information*").

The latter learning dimension of the PP has clearly been one key component of the ^{S}PP right from the beginning, in line with views coming from the analysis of the irreversibility effect in a dynamic sequential setting. For instance it has arisen as a critical issue in expert debate about optimal timing for tackling global warming, when multiple source of inertia and prospects of better information are taken into account together with induced technical progress (Manne and Richels [1992]; Grubb et al. [1995]; Hourcade [1997]; Ha-Duong *et al.* [1997]; Ulph and Ulph [1997]; Webster [2000]). It is also at the core of admitted exceptions in WTO rules (specially the Agreement on Sanitary and Phytosanitary Measures, SPS) and the Cartegena Biosecurity Protocol related to the international circulation of GMOs (Montreal, January 2000). These agreements allow States to take provisional measures against food or GMOs imports in the name of hazards affecting food safety or the environment, even if they cannot immediately show full scientific evidence supporting their allegations: States have to prove that they are actively committed to resolving existing uncertainty in a reasonable time limit. For instance, article 5.7 of SPS Agreement reads:

> "*In cases where relevant scientific evidence is insufficient, a Member may provisionally adopt sanitary or phytosanitary measures on the basis of available scientific information, including that from the relevant international organisations as well as from sanitary and phytosanitary measures applied by other Members. In such circumstances, Members shall seek to obtain the additional information necessary for a more objective assessment of risk and review the sanitary or phytosanitary measure accordingly within a reasonable period of time.*"

Referring to learning and provisional measures in interaction with scientific developments is also part of the interpretation of the PP officially given by the European Commission [2000] and endorsed by the European Council of EU member States at the meeting of Nice in December 2000. This is what is explained in the principle 5:

> "*Maintenance of the measures depends on the development of scientific knowledge, in the light of which they should be reevaluated. This means that scientific research shall be continued with a view to obtaining more complete data.*
>
> *Measures based on the precautionary principle shall be reexamined and if necessary modified depending on the results of the scientific research and the follow up of their impact*".

Lastly, I will mention the 5th and 6th commandments of the 10 Commandments of Precaution stated in the report by Kourilsky et Viney [2000, p. 56]:

> *"V- Decisions must, as much as possible, be revisable and adopted solutions must be reversible and proportional (Les décisions doivent, autant qu'il est possible, être révisables et les solutions adoptées réversibles et proportionnées).*
>
> *VI- Going beyond uncertainty requires an obligation of research (Sortir de l'incertitude impose une obligation de recherche)."*

Whatever important the learning dimension may be for ^{S}PP, it would be wrong to think that it overwhelms the whole rationale of ^{S}PP, as will be shown thereafter. Some statements are quite excessive to this regard, as the one of von Schomberg, from the EC staff [1998]: "*It is very important to note that precautionary regulation can never be aimed at a categorical ban on products or experiments*."

(2) According to the Bayesian framework, the stylised problem sketched by Gollier *et al.* concerns a Robinson who has to make his own decisions regarding risky prospects, while the ^{S}PP is placed right at the beginning in a context of social co-ordination for tackling collective risks. The idea of a 'Principle' in the ^{S}PP means that it is not only an 'approach' or a 'psychological attitude' adopted by individual agents, but a statement defining a public direction for collective choices and public policy. That move from an individual to a collective context induces going beyond the mere assumption of individual subjective probabilities informing individual decisions. Since a priori subjective probabilities may greatly differ from one agent to another, they raise the issue of social procedures to aggregate individual preferences regarding potential hazards, or alternatively to come to a shared view on the public strategies of precaution. In that, ^{S}PP is just a new case underlining the problem raised by public choices. But there is more.

Why have standard prevention strategies given primordial importance to the issue of getting scientific proof of the existence of a hazard, and endowed experts with a prominent role for guiding policy? It should be understood in the context of the specific requirements of justification in collective settings (Boltanski and Thévenot [1991]). Justification implies the quest for common references to come to an agreement about the problem to solve by public action. Inasmuch as such elements could be provided by science, this was best supplied by objective facts, results and proofs since, according to the dominant interpretation of objectivity, the latter embraces 'realities' and 'statements' that could not be denied by anyone after an informed public discussion. The individualistic framework of the model of Gollier et al does not consider such requirements and achievements.

Thus, in a symmetric way, this model cannot identify and address the new and specific difficulties raised by the ^{S}PP for policy-making, in searching for a legitimate and accepted basis for calibrating precaution strategies. With the ^{S}PP, reference to objective facts as a basis of decision-making is now substituted by unequally plausible and unequally consistent scientific assumptions under conditions of scientific and/or social controversy (Godard [1992], [1997a], [1999]). This change implies *inter alia* that it is no longer possible to assume a unique and common expert assessment of hazards: on the one hand, several groups of experts may come to different conclusions and priorities and these divergences cannot be explained just by the fact that good science would have suffered from the interference of junk science; on the other hand, within one expert group, some dissident views may legitimately appear and cannot be dismissed[6]. Scientific controversies and dissents are frequently used and

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[6] The Resolution on the Precautionary Principle adopted by the European Council of Nice says: "*that an assessment of risk must also report any minority opinions. It must be possible to express such opinions and bring them to the knowledge of the parties involved, in particular if they draw attention to scientific uncertainty*" (l'évaluation du risque doit également faire ressortir les avis minoritaires éventuels. Ceux-ci doivent pouvoir s'exprimer et être portés à la connaissance des acteurs concernés, en particulier dans la mesure où ils mettent en évidence l'absence de certitude scientifique).

amplified by social controversies about the right precautionary policy to decide on. Decision-makers are no longer exposed to a unique objective expert vision of the problem but face several contrasted ones, without any possibility to choose between any of them on a scientific ground. So contexts of scientific uncertainty make issues of aggregation, representation and co-ordination much more critical than for the prevention of known risks; for the latter, those issues are mainly solved by obtaining objective assessments from experts.

(3) Whereas the ^{S}PP enables public authorities to take preventive measures for hazards that are just potential, for the ^{B}PP precaution only means 'more prevention' in a context in which there should already be some, under an inert state of knowledge and beliefs. To a large extent, the practical breakthrough of the ^{S}PP just comes down to allowing prevention in public decision-making for cases in which such prevention was lacking but would already have been justified according to ordinary standards of economic thinking about risk decision. To this extent, the ^{S}PP helps put an end to an economically unjustified state of affairs in public hazard management. Therefore, the alleged conceptual breakthrough brought by the ^{S}PP is partly a socially effective illusion that permits to organise standard prevention properly. But there is more than this illusion in the ^{S}PP, since it also involves a new understanding of the relationship between knowledge and action (see thereafter).

(4) Both approaches take incomplete knowledge as granted and nonetheless stress the urge of taking immediate preventive action. But they diverge in the way to position precaution in regard to incomplete and uncertain science: the ^{S}PP means that action may or must be taken in spite of existing uncertainty about the existence of a danger; Gollier *et al.* contend that the precautionary effect is characterised when more immediate prevention is decided because of present scientific uncertainty, since that is supposed to mean that there is some prospect of having better information in the future. Beyond a common acknowledgement of relevance of incomplete knowledge, both concepts express different attitudes nonetheless: the ^{S}PP does not necessitate a future improvement of information in order to justify a precautionary early action, whereas ^{B}PP strictly attaches the precautionary effect to such a prospect. So what Gollier *et al.* described may be part of the ^{S}PP rationale, but does not constitute the whole of it.

Such a difference is also related to another issue: the dimension of irreversibility of damage once the latter is achieved. With ^{B}PP, two different effects combine together to justify more immediate prevention: the precautionary effect and the standard irreversibility effect, both related to the prospect of improving information. In that case, irreversibility is not critical for the conception of precaution delivered by the ^{B}PP and represents just an amplifying factor. Meanwhile, threat of irreversible environmental damage has triggered impulse in favor of the ^{S}PP, as is attested by the nature of issues for which it has been mobilized: biodiversity loss, global warming, ozone layer depletion, alteration of marine ecosystems such as North Sea, nuclear waste management, and general statements about sustainable development. Irreversibility is explicitly quoted in major law texts to qualify circumstances under which the ^{S}PP should be mobilized to justify early prevention. This focus on the threat of irreversible damaging evolutions can be such that precautionary strategies are conceived without taking any account of the prospect of an improvement of scientific knowledge in the future, i.e. of what constitutes the central condition of ^{B}PP. This is the reason why the provisional management of the wait may be abandoned by ^{S}PP and substituted by a commitment to long run action plans that attack all potential sources of a given potential hazard. There is no better illustration of the latter than the 1995 Esbjerg Ministerial Declaration at the end of the 4th North Sea Conference of Ministers:

> *"The Ministers agree that the objective is to ensure a sustainable, sound and healthy North Sea ecosystem. The guiding principle for achieving this objective is the Precautionary Principle. This implies the prevention of the pollution of the North Sea by continuously reducing discharges, emissions and losses of hazardous substances thereby moving towards the target of their cessation within one generation (25 years) with the ultimate aim of concentrations in the environment near background values for naturally occurring substances and close to zero concentrations for man-made synthetic substances."*

Although the same declaration states that "*in this work, scientific assessment of risks is a tool in setting priorities and developing action programmes*", it is clear that the ^{S}PP is in this text not principally conceived as a means of managing the wait. Is it really precaution or is it still usual prevention? I contend that we face here with one authentic mode of existence of precaution: (1) it addresses potential hazards without getting full knowledge about causal chains involved and the precise effect of identified factors; (2) differing from prevention strategies like those implemented on the basis of epidemiology, action is not determined by a statistical analysis of risk factors and the knowledge of probability distributions but by hypothetical reasoned imputations of potential hazards to potential sources. This second mode echoes the Jonas' argument: we should do everything that is possible to avoid the possibility of future catastrophic development for humanity and to be successful in this endeavor we should tap on the resources of imagination and sensitivity to supplement[7] rational knowledge.

Consequently, it should be recognized that the ^{S}PP embraces two very different modes of action. The first one can be said to be 'tactic' and is used as a means to manage prudent action in close interaction with the progress of a scientific knowledge initially marked by incompleteness and uncertainty. The second one can be called 'strategic' and is focused on a long-term strategy of reduction of all sources potentially involved in the generation of a given potential hazard. Because of these two different modes of existence, the ^{S}PP cannot be used as a self-satisfying, homogenous criterion for decision-making: ^{S}PP is definitively not a criterion, but a more general benchmark, a principle. Accordingly, the ^{S}PP obliges policy-makers to take potential hazards into account but it does not impose any specific decision framework for defining priorities and assessing options. With the ^{S}PP, a key question is let open: given an empirical context, is it appropriate to adopt the tactic mode or the strategic one?

2.2. About the links of precautionary actions with the development of science

2.2.1. Why does more science mean more ex ante uncertainty?

Development of science and progress of knowledge play a critical role in the ^{B}PP. As previously mentioned, expecting or not expecting improvement of information about a hazard

[7] Jonas says 'supplement', not 'substitute'!

is supposed to be the starting point between standard prevention and the ^{B}PP. Inasmuch as precaution is defined as more immediate prevention with the prospect of getting an improved information in the future, there is at first sight some embarrassing paradox in the theory. How can such a prospect, translated for example by an expectation of a future smaller variance around mean value for the risk magnitude, be seen as increasing *ex ante* uncertainty and justify more immediate prevention than in the absence of new information, without putting some irreversibility effect in balance? Gollier *et al.* provide two slightly different arguments (p. 231 and p. 239) for a conclusion that is only valuable for some utility functions (belonging to the class of Hyperbolic Absolute Risk Aversion – HARA) and some probability distributions (small risks and two-point support). ^{B}PP is attributed to the net result of two opposite effects:

(1) the prospect of better information means an aptitude to choose actions that will be more adapted and proportionate to the real nature of hazards, resulting in a reduced expected loss of income; better information induces a wealth effect; the expected level of future consumption being higher with this prospect, it would be optimal for the agent to allocate less resources to risk prevention in the first period; then, the risk exposure in the future would be increased relatively to the case without information gain; then prudent agents would reduce their immediate consumption to save more income for the future; since there are two opposite effects (the wealth effect produced by a more efficient response to risk and the precautionary effect) the general result would be ambiguous if one of them does not take advantage on the other; the ^{B}PP is validated when the precautionary effect is bigger than the wealth effect;

(2) the prospect of getting an improved information means that the *ex ante* dispersion of probabilities relative to possible states of nature will increase (with very poor information, every occurrence tends to be seen as equally probable), since the decision-maker does not know *ex ante* in which direction the improvement of information will go; then "*risk exposure will be sensitive to more extreme signals*", thus increasing *ex ante* uncertainty.

With the first presentation of the argument, increased *ex ante* uncertainty about future hazards proceeds from a lower level of prevention in the first period (or an increase of immediate risk-generating consumption), while with the second, it is an increased sensitivity to extreme signals that is involved.

As a matter of fact, Treich, who co-authored the article of Gollier *et al.*, involuntarily suggested another explanation in another paper [1997]. After having introduced the idea that the precautionary effect is related to the very nature of scientific uncertainty, as a promise of progress of scientific knowledge in the future, he identifies the following one: "*Doubts about scientific discoveries to come are an additional source of uncertainty*". For the author, this statement meant that we do not know *ex ante* which discovery is going to be made (there may be surprises). But it also means that we may have doubt about the real progress of knowledge that will be obtained; we do not know if science will succeed in resolving uncertainty (there may be no discoveries). With scientific uncertainty, there is a prospect that scientific research will result in an improvement of information, but there is also an uncertainty about this prospect. This remark can be developed into two directions that have been important in the discussion about ^{S}PP.

Firstly scientific development cannot be assimilated straight away to a regular improvement of information about a potential hazard; in the time-scale relevant for organizing prevention, we may face several different occurrences. Science may stay indecisive for a long while on the existence or non-existence of a potential hazard; or progress of scientific knowledge may mainly concern variables that are irrelevant for deciding a strategy of precaution. In those cases, scientific progress does not result in better practical information for policy-makers, even if, by itself, a long lasting inconclusive state of knowledge is a crucial element of information that there are no straightforward major links. Such information was not available at the beginning of the process of scientific research. Science may also discover unanticipated new phenomena that increase, at least for some time, the dispersion of results from models. More precisely, it may happen that models give a larger range of plausible results or that various results obtained by different teams deliver increasingly divergent results. Both occurrences increase *ex post* uncertainty. Progress of knowledge often takes the form of a discovery that things were 'more complex than previously believed'.

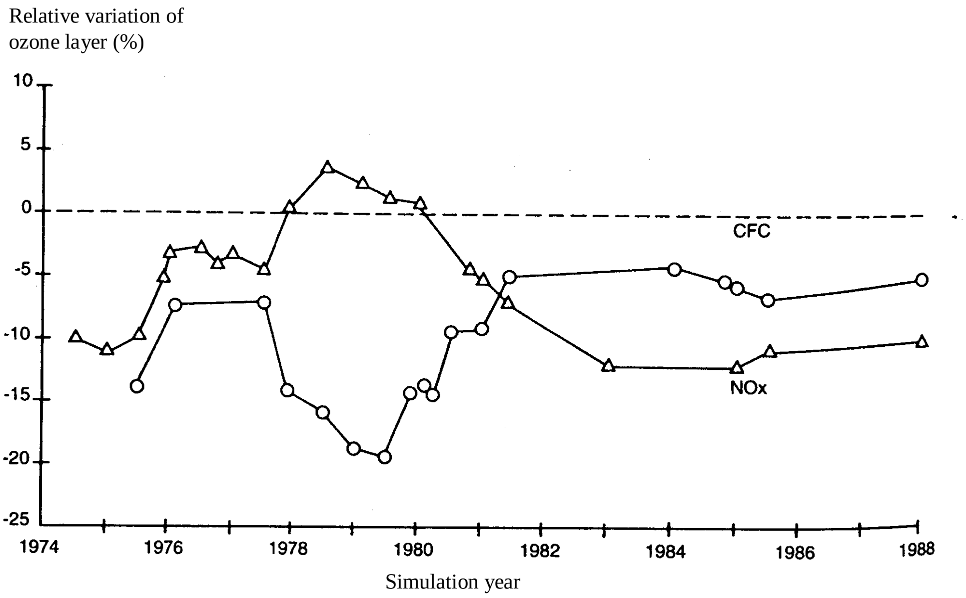
This kind of story happened for the chemistry of ozone production and depletion in the stratosphere (see figure 1) when one found out that the ozone layer answered by completely new interactions when exposed to high levels of pollutants, a situation that had never been experienced by nature in the past. Taking account of newly discovered factors or relationships, the dynamics of knowledge do not generally follow a pace of regular improvement in the precision of the information structure but alternate phases of convergence of results and phases of increasing divergence across models; the range of extreme values given as best estimates (upper and lower limits) at one time are regularly exceeded in the following periods (Hammit and Shlyakhter [1999].

In other words, science is a venture the result of which cannot be predicted, even in terms of time delays needed to come to a satisfying picture for decision-making. So I will certainly support the view that on the medium term, the prospect of having scientific programs should be considered as a factor of increasing *ex ante* uncertainty. But this argument is different from the one of Gollier *et al.* for which uncertainty comes from the prospect of an improvement of information.

Secondly, the issue at stake for ^{S}PP is not so much an intrinsic variation of uncertainty about a potential hazard but the impact that this variation may have on the decision problem. Two structural factors influence the way decision may be affected: the variation of the list of potential causes of a given hazard (the dynamics of the scientific competition between theories) and the framing that alternative theories impose on actions if the latter are intended to be efficient in terms of appropriate intensity and timeliness. A third one is related to the sensitivity of decisions to a change in information: to what extent variation of uncertainty on a given hazard is able to produce a bifurcation in existing prevention strategies? The latter may have some robustness, not being affected by a variation of information contained within some range. For instance the first 1990 IPCC report on climate change mentioned a 1.5 to 4.5°C increase of global mean temperature in 2100. The 2000 IPCC report extended the upper bound to 5.8°C. To what extent does it change the strategy to follow during the next two decades? Not much, or maybe nothing at all! Many scientific developments do not represent an improvement of information if they are not sufficient to change the relative order of different strategies. On the contrary, around a decision bifurcation, small variations in information may produce a shift in strategies. It is the prospect of an induced change in action course that increases an *ex ante* decisional hesitation and subsequent incapacity to plan action.

This is what really matters to qualify relevant uncertainty and relevant scientific progress.

***Figure 1**: Evolution of scientific predictions of impacts of NOx and CFCs on the stratospheric ozone layer depletion through time (1974-1988)*



from Mégie [1997] p. 226

Before 1986, the figure shows the variations of the best estimates of different modelling exercises regarding the impact of CFCs and NOx on the ozone layer according to the publication year of the results. After 1986, there has been a period of relative scarcity of results of models because a new disequilibrium chemistry of ozone production and depletion was discovered with entirely new values. Models had to be deeply changed.

Thus, according to Hammit and Shlyakhter [1999], *uncertainty* about the value of a hazard parameter and *informativeness* (the extent to which current uncertainty may be reduced) cannot absorb the whole discussion about what an improvement of information is. Two other heuristic factors have to be considered: *promise* (the probability that improved information will result in a different decision and the magnitude of the resulting gain) and *relevance* (the extent to which uncertainty about the parameter contributes to uncertainty about which decision option is preferred). Another proposal is put forward by Chevassus-au-Louis [2001], who suggests to build a scale of uncertainty on the basis of three variables: *plausibility*, computed as the product of the quantity of observations or studies on a given matter and the degree of consensus among experts; *informativeness*; and *observability* (the extent to which a hypothetical phenomenon can be identified by realistic observation procedures). The third variable – *observability* - is important in collective contexts by focusing on the possibility to introduce an empirical test of reality, echoing the search of an objectivity that could be shared by all parties.

With the ^{S}PP, groups of experts involved in assessing decision issues should consider such factors to frame their characterization of present states of knowledge and scientific uncertainty related to a given potential hazard. While *parameter uncertainty*, *informativeness* and *observability* can be assessed by scientists specialized in the concrete domain of concern (climatology, ecological sciences, medicine, etc.) in their own terms, *relevance*, *promise* and *plausibility*[8] clearly depend on the characterization of the decision problem, notably the identification of the possible decisions at hand and the scope and magnitude of their consequences. Such a task requires other kinds of experts (decision analysts, economists, law specialists) and needs a concrete interaction with the circles of decision-makers concerned. One leitmotiv of risk analysis is the separation between stages of risk assessment, risk management and risk communication. But, whereas an institutional distinction of roles is essential for the credibility and transparency of the whole process to the public, under the ^{S}PP this distinction certainly should not be interpreted as an intellectual separation: the way experts frame their assessment of potential hazards has to be relevant and meaningful for managers and the concerned parties. In this way precise interactions should be organized between experts and decision-makers to set the scope of expertise. Distinguishing roles and responsibilities is a positive feature for the credibility of the whole process, but should be understood as a means to formally organize relationships and exchange of information between scientific experts and managers. From this point of view, the ^{S}PP is not only relevant for risk management but also for risk assessment.

2.2.2. Allowing some risk-generating activities as a scientific experiment to gain information on potential risks

In their model of ^{B}PP, Gollier *et al.* consider the risk level to be endogenous, since the future level of risk depends on consumption behavior in previous periods. In fact they specifically deal with accumulative or stock-type classes of risks. But regarding ways and means to obtain improved information, they assume a Bayesian revision of beliefs based on scientific developments, i.e. an external source not directly linked to the level of the risk-generating activity or technology. This restriction is quite acceptable for analytical purpose; it is nonetheless a source of limitation for the generality of results in the way to understand the PP. With their model, reducing immediate consumption will at the same time reduce the future level of risk and allow, through savings, an increased consumption in the future without any loss in the future information about the risk. This may be a good proxy for the problem of global warming, but certainly not for issues like GMO releases for which the ^{S}PP is also supposed to be relevant.

In cases such as GMOs, it is very difficult to gain improved knowledge on potential hazards without experimenting hazard-generating activities outside laboratories at some stage and at a sufficiently large scale to provide good insights on real-size dangers. This experimental strategy may be chosen for cost reasons (for instance, research programs on fish population dynamics using the statistics of caught fish as basic data will avoid the cost of

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[8] Against all expectations, dependence on decision frames also holds for *plausibility*: having in mind a qualitative or discontinuous scale, the different levels or thresholds of the scale used to assess *plausibility* should make sense for normative judgments and making decisions. Even under ^{S}PP, it is not conceivable to give the same practical influence to pure, but not-invalidated conjectures and to hypotheses that, although not definitely proven, are supported by elaborated theoretical models and pieces of empirical results coming from the laboratory or field observations. Experts do not have to decide on precaution strategies but the framing of their analysis of *plausibility* should be in line with the thresholds considered as meaningful to decision-makers.

specific programs of data collection that would have to be implemented separately) or because an empirical study of real world phenomena is necessary to improve the understanding of the nature of dangers. In those cases, it is necessary to take risks to learn about hazards. But in order to be able to learn from risky actions (for instance GMO dissemination), the latter should be organized in such a way as to produce maximum relevant and reliable information according to scientific criteria: risky actions have to be shaped and followed-up as a scientific experiment. This means that they should follow a strict protocol of procedures and avoid massive introduction from the very beginning. Inasmuch as benefits of risky actions are initially not well known either, accepting controlled commitment to risky actions would also improve the knowledge of benefits of the activity. The same could be said about the precautionary measures if their implementation is conceived as a means of learning more about both their efficiency and the nature and magnitude of hazards. This was what von Schomberg [1998] asked for: "*In the context of incomplete scientific knowledge, it is even necessary to gain practical experience with products or experiments in order to complete scientific knowledge and for identifying actual risks. The accumulation of scientific insight by precautionary use enables the update of standards for risk assessments*".

This approach would put into question a linear approach of precautionary strategies where risk assessment comes first once and for all, and decisions about authorizations and bans come at the end without any feed-back. Similarly turning ^{S}PP into an 'abstaining rule' and the search of 'zero risk' would entail a clear opportunity cost in terms of scientific knowledge of hazards and how to mitigate it or to adapt to it. Instead, more intricate relationships have to be settled between a broad risk assessment process and reasoned commitment to risky actions. Under a ^{S}PP regime, action embraces both preventive measures and commitment to risky actions. The latter are then conceived to improve knowledge of benefits and hazards, and are calibrated to entail only an *ex ante* accepted level of risk. Put in expressions, precaution is "*Act to learn to act to learn…*" at the same time as "*Act then learn then act then learn then…*" that became familiar in the global warming debate (Manne and Richels [1992]; Hourcade [1997]).

If, in ^{B}PP, learning for the future were just a continuous function[9] of the level of consumption of the risk-generating product in the first period, what would be the expected analytical consequences? More immediate prevention would mean less knowledge in the future, less wealth effect and also less *ex ante* uncertainty, which would be in favour of more immediate consumption according to the model of Gollier *et al.*; but more immediate consumption will allow additional learning, and entail more *ex ante* uncertainty, and so on. Since we have two opposite movements, a new equilibrium would have to be found with more immediate consumption that could not be seen as less precautionary. Models with endogenous information would presumably catch this effect more easily (Richard and Trommetter [1999]; Richard and Trommetter [2000]). In the GMO debate, a sequential precautionary approach can initially consist of selective authorisation of field experiments – they should be selective in number and magnitude of superficies -, after passing the appropriate laboratory tests, in order to allow risk managers to stop them if unexpected difficulties occur. A progressive extension of dissemination would be contemplated after some learning periods, but still placed under planning and co-ordination constraints

[9] It is certainly not a good assumption in practice since the learning effect will require a minimal level of commitment to risky action and also depends on a specific organization responsible for the follow-up.

(regarding the choice of variety and location according to proximity constraints). Conditions of *observability* would be important to determine the conditions and the pace of administrative authorisations.

2.2.3. What about a Bayesian framework?

According to the Bayesian assumption, ^{B}PP assumes that it is always possible for any agent to set up a subjective distribution of probabilities about a potential hazard. This framework voluntarily ignores the empirical grounding of the distinction between risk and uncertainty. Meanwhile, it is very frequent in complex issues concerning potential hazards that groups of experts (committees, commissions, …) do not accept to give probability distributions about their existence and magnitude because of the fuzzy understanding of basic phenomena at stake (case of mad cow disease in Europe or IPCC reports on global climate change). When they accept to give upper and lower values around a central value, they accompany the statement with strong warnings that the central value has no reason to be more probable than any other, and that surprises driving hazards out of the range cannot be ruled out, i.e. the confidence in the range of values is not very high (cases of stratospheric ozone layer and global warming). Neither objective ranking nor full characterization of possible outcomes is at hand in those contexts for which the ^{S}PP has been conceived. As Von Schomberg [1998] put it: "*The scientific uncertainties concerning the subject matter also imply the impossibility of a full quantitative risk assessment whenever the precautionary regulation is implemented*", although authorities do find intellectual comfort in asking for strategies of precaution to be implemented on the basis of a scientific evaluation as complete as possible. In domestic and international contexts, it is a usual source of conflict about the legitimacy of precautionary measures. But it is remarkable that the WTO's Appellate body, in the case of growth hormones for beef, had to reject the panel's initial interpretation that the risk assessment had to be quantitative and establish a minimum degree of risk. They had to recognise the legitimate use of qualitative information or singular factual events (Noiville [2000]).

In such contexts, policy-makers need to find other landmarks than their own subjective perceptions. The latter may be both quite misleading and lacking of public credibility when they are not informed by appropriate expertise. This is the reason why debates about the role and organization of expertise have been so intense for the implementation of ^{S}PP (Godard [1997a], [1999], [2001a]; Kourilsky and Viney [2000]; Chevassus-au-Louis [2000]). When experts do not deem the recourse to probabilities credible, how may one give directions to the work of those experts and make use of their results?

Kourilsky and Viney [2000] suggested organizing expertise in two circles. The first one should be dedicated to the scientific and technical examination of the nature of potential hazards with the aim of identifying the danger, its generating factors, the population exposed and its possible incidence. This approach is quite in line with standard risk assessment, with a greater focus on transparency on sources and magnitudes of uncertainty. Being factual and objective, and not normative, even if it is supported by assumptions and abstract arguments, this first type of expertise alone does not provide an appropriate basis for making decisions on prevention strategies. Thereby an often forgotten second circle of expertise is to be devoted to an economic and social appraisal of potential hazards, that will both consider the play of economic and social factors in the modulation of risks in real-life conditions (see box 1) and place them in an economic and social value framework. According to these authors, this second circle should be opened to various stakeholders and not only to professional economists and social scientists, thus forming a hybrid forum. Such a general framework could accommodate the two different mode of existence of the ^{S}PP, as it is now described.

Box 1: A case for an economic expertise to support public risk management: the BSE embargo crisis between France and UK in 1999 (Godard [2001a])

In autumn 1999 the French government decided not to follow a decision of the EU Commission and to maintain an embargo against UK imports of bovine meat. Due to a potential risk of dissemination of BSE, the French safety agency AFFSA had given a negative opinion. But an argument seemed to have been important for the government's decision: social equity. According to the perception of the French government, UK meat would be of a rather low quality level and cheap; consequently, if the choice were to be let to consumers, even appropriately informed by labelling and traceability, poor people and people depending on collective catering (elder people in hospices, children…) would be the most affected by the BSE risk, which was considered unacceptable as socially unfair. But this perception has not been based on an independent and transparent economic expertise about the running of meat markets, since AFSSA is only in charge of a biological and health expertise. In fact due to stringent prevention measures finally taken by the UK government to ensure the quality of meat for exports, UK meat that could have gone to France was not cheap. There was no chance of seeing it concentrated in the plates of the low-income or dependent groups, just for economic reasons. A possible counter-argument is that UK exporters could choose dumping prices to sell their beef. Was it probable? In the context of general fear of BSE, and distrust in UK beef and effective traceability allowing a clear identification of geographical origin, this would have been a self-defeating commercial strategy. To find a market, UK beef exporters would have been condemned to adopt a reputation strategy incompatible with low prices. In any case, in order to improve the quality of information supplied to political decision-makers, various arguments and scenarios should have been considered and discussed by specialised groups of economic expertise ruled by the same principles of independence, pluralism and transparency that have been chosen for the biological and health expertise. And they have not.

2.2.4. When science is distrusted as a guide for precautionary strategies

Some groups in society, including NGOs that increasingly gain the trust of the public (Jensen [2000]) expect the ^{S}PP to protect society against failures of scientific method. As Santillo et al ([1998], p. 939) put it, "*It was recognition of the limitations of scientific knowledge that led originally to the formulation of an approach to environmental protection which was fundamentally precautionary in nature.* (…) *it must be recognized that risk assessment captures neither the spirit nor the intentions of the precautionary principle*". This is what leads Stirling *et al.* [1999] to claim after late Winston Churchill that the "*science should be on tap not on top*". Those attitudes basically express what has become a component of the situation of risk management: the loss of faith of part of the public in the ability of science to bring proofs based on precise causal relationships between natural processes or human action and environmental damage in due time. For people having a mid or radical distrust in science or institutions in charge of managing collective risks[10], which is not by itself an unreasonable position[11], the precautionary strategy should not be made too dependent on scientific events. Instead, it should consist of a plan of progressive eradication of all potential sources of potential damage whenever technology provides feasible alternatives to current practices. This approach is for instance in line with the Esbjerg declaration, that may be credited with a paradigmatic value of the 'strategic' concept of ^{S}PP.

It is then expected from experts to identify possible hazard factors and prioritize action on them. According to the strategic concept of ^{S}PP, issues related to convenience, technological facility, social acceptability, economic costs would be of critical importance, more than detailed scientific assessment of hazards, flawed by all the unknown and hidden social values behind the apparent objectivity of expertise. It means that the type of expertise needed should be adapted: prominent scientists in the field of biology are less desired than people having a good knowledge of the concrete running of activities in the real world. The second circle of expertise would be the most important one.

For instance, in the case of the mad cow disease, targeting systematically potential sources of hazard, under the double constraint of possible emotion of public opinion and professional acceptability in cattle-raising and agribusiness, seems to have been the core of the strategy of the French government, as illustrated by the ban in 2000 of any use of bovine intestine[12] in the food chain and of any meat and bone meal (MBM) to feed any species of animal. In that context expertise of AFSSA only partially fitted with the decisional requirements of this strategy.

2.2.5. An iterative process between knowledge in progress and precautionary strategies

The second direction for positioning scientific expertise under ^{S}PP corresponds to its 'tactic' mode, more in line with the analysis and proposals of Kourilsky and Viney. It is expected from expertise to provide a characterization of available scientific information on potential hazards in the terms I previously introduced: *uncertainty range*, *plausibility*, *informativeness*, *observability*, *promise* and *relevance*. All this is aimed at assessing the level of consistency of alternative scientific statements, and at allowing reflection on the policy influence they should deserve. For instance it should be discussed and decided which assumptions can be judged

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[10] For an empirical study of trust and distrust of the public in scientific information and expertise, see for instance Jensen [2000].

[11] Since there have been remarkable failures in the past risk management (AIDS and blood transfusion, mad cow disease, asbestos-induced cancers, late regulation of overfishing, long lasting industrial pollution of soils, etc.) although public authorities responsible at the time of taking preventive measures said situation was under control, it is quite reasonable for the general public not to trust new promises from the same authorities and to have suspicion that they could be captured by some sectoral or business interests. For the past management of the mad cow disease in the UK, precise failures involving public authorities have been identified for the 1985-1996 period by the report of the Inquiry asked by the UK government to the Committee chaired by Lord Phillips of Worth Matravers [2000].

[12] All parts of intestine have been banned because they may include pathological forms of prion proteins, although experimental tests of infectiosity have been positive only for ileum: using mice as models, injections in mice brains of intestine extracts of mad cows(excluding ileum already known as an infectious source) have not been sufficient to trigger a pathological evolution (AFSSA [2000]).

plausible enough to deserve consideration and trigger preventive measures stronger than mere additional efforts in research. Accordingly, ranking the consistence of scientific warnings about hazards on an ordinal scale, analogous to Richter scale for earthquakes, could allow a correspondence with a ranking of options of action, from simple scientific watchfulness to strong measures forbidding products or technologies. Instead of conceiving the ^{S}PP as a binary criterion (authorization or ban), a precautionary strategy has to be organized in such a way to be gradually more stringent according to an increasing plausibility and consistency of scientific representation of potential hazards, for a same level of expected damage. Then, only sufficiently consistent statements could lead to the strongest preventive measures. Such a way to proceed would echo the idea of “proportionality” that is in the heart of the legal definitions of ^{S}PP. Precautionary measures also are regularly revised according to the improvement of knowledge along the lines introduced in previous sections.

2.2.6. Two types of relationships for two modes of the ^{S}PP

The conclusion of this section is the following: in the present state of public debate and policy responses to environmental and health challenges, ^{S}PP embraces two different rationales of prevention which add to standard justifications: (1) the first one manages the waiting for new scientific development supposed to improve the knowledge of hazards and is very sensitive to events affecting scientific activity; early action and revision of provisional measures on the basis of progress of knowledge constitute the core of this approach; (2) the other one expresses scepticism about the ability of science to deliver the final word about complex matters and expect that precautionary strategies will put a concrete end to threats of potential dangers by a progressive eradication of their possible sources. Both modes imply different things for expertise and the type of relationship between scientific knowledge and decision-making.

With the ‘strategic’ one, scientific developments are not overlooked but they are ranked in second position behind practical aspects of implementation (technological feasibility, cost for business firms and consumers, etc.) and do not interfere with strategic targets, which are chosen without expecting much of science. Society does not want to be exposed to a given potential hazard, even if, in doing so, it renounces to the possibility of knowing more in the future about the very existence and the magnitude of the hazard of concern. Consequently it renounces too to learn about the necessity to maintain the costly measures necessary to absolute prevention.

In both cases, efforts to find a good articulation between expertise and decision-making could be supported by the development of analytical models based on non probabilistic frameworks that accept more qualitative and rough framing of information, since in practice, none of the two modes of existence of ^{S}PP accept a generalized use of subjective probabilities by experts.

3. The contribution of economic and decision theory to reasoned ^{S}PP heuristics

Analytical models such as Gollier *et al.*’s ^{B}PP contribute first to their own scientific purpose regarding the development of formal economic theory. They cannot be expected to be directly relevant in an empirical context for policy purpose without specific intermediate models and analysis taking over. The link should be established on the basis of an appropriate sketching of stylised facts that specify relevant empirical contexts. Meanwhile, analytical models provide key ideas and insights that may positively contribute to the shaping of ^{S}PP heuristics. Clearly, for instance, the main directions and principles claimed by the European Commission and the European Council for the implementation of the ^{S}PP echo some basic features and results of economic theory and risk analysis[13]. It is the case for the need of a scientific assessment and the ideas of proportionality, coherence and reversibility of precautionary measures to take advantage of improving information. Similarly the requirement to compare what is achieved for a given hazard with what is done for other similar hazards and to take irreversibility into account through early prevention and actively developing knowledge are in line with economic thinking.

What is challenging with Gollier *et al.*'s ^{B}PP is the link established between the intensity of immediate prevention and the prospect of an improving information: more prevention today may be justified for prudent agents not only because of the threats of irreversibility of damage but also because of the very prospect of future improvement of information. As I see it, after transposition in a decision-making framework, an effect of this sort could take place because a prospect of improvement of information suggests that the course of action should be revised, which implies more *ex ante* indecision about how to plan action through time, and the need to transfer additional resources to the future in order to secure the ability to face a new informational situation. But what do we know about the conditions of the emergence of the precautionary effect? Do they have practical meaning? Gollier *et al.* identify theoretical conditions for this effect to take place. One important condition is that absolute prudence should be at least twice as high as absolute risk aversion ($P \geq 2A$). Authors and commentators agree that it is not straightforward to translate this condition in practical settings, since it is related to the ratio of the third derivative to the second derivative of the von Neumann-Morgenstern utility function, and these derivatives are not observable variables. So I do not suggest that this value should be considered in applied cost-benefit studies that are achieved to enlighten public investment decisions or regulatory risk management. It will not fulfil the requirements of a heuristic value. Meanwhile I suggest using Gollier et al.'s results in other directions.

3.1. On different strategies to reduce indecision

The same sort of initial features (i.e. a framework of present collective indecision resulting from both a high level of present uncertainty and the prospect to resolve it in the future, together with a presumption of a rapid irreversible evolution of physical states) have been documented in the case of forest-decay in Germany and Europe in the 80ties (Boehmer-Christiansen [1990]; Hourcade et al. [1992]; Godard [1992], [1997a]). These researches have

[13] This is acknowledged by John Graham ([2001], p. 110) from the Harvard Center of Risk Analysis : « *The precautionary principle need not be the dangerous concept that some scientists and technologists fear. (…) While some authors continue to expound the notion that the precautionary principle is a viable substitute for risk analysis and management (Santillo et al. [2000]), or the notion that the principle means that proponents of new technologies 'should be required to provide conclusive evidence of their safety' (de Sadeleer [2000]), these views are not tenable in the context of the 1992 Rio definition of the principle, the February 2000 Communication by the European Commission, and the preliminary indications from the European Parliament* ».

shown how at some moment, in spite of conflicting positions about what should be done by the government, a coalition of actors urges public authorities to take measures without waiting for a scientific resolution of uncertainty. Their goal is not so much to optimally solve the problem (nobody knows for sure if measures will succeed because nobody can convincingly attribute the problem to precise and exclusive factors) but to stabilise the future context of action of various agents, in particular of business firms involved in industrial activities. Big industrial firms need a predictable environment and, generally speaking, prefer a second-best known and stable regulatory framework than fuzzy prospects about future rules of the games. "*Persisting uncertainty suffered by economic actors is then expected to be reduced by setting social conventions and rules, even arbitrarily. (…) At this very moment, contextual stabilization cannot be deduced from 'hard facts' or scientific consensus. (…) (it) is generally based on the more sound elements at hand in the situation: available technologies that have reached an operational stage and are supported by a network of actors and corporations having vested interests in their development. At this very moment, the social process is gaining autonomy as regards the future evolution of scientific controversy*" (Godard [1997a, p. 48]. There is a price to pay for this rather early stabilisation of public action. It includes several components: the immediate use of scarce financial resources; adoption of technologies that are not the most efficient to tackle the problem, considering the legacy of past R and D when the problem still had not arisen; the risk of having opted for a solution without significant or sufficient action on the problem of concern; the difficult reversibility of regulatory frameworks that are supposed to stabilise prospects for action, even if they do not fit with the subsequent evolution of knowledge[14].

The price paid for a reduction of the indecision generated by both scientific uncertainty and the prospect of its future resolution can be seen as an empirical confirmation of the relevance of the result of Gollier *et al.* Meanwhile the price paid does not necessarily take the form described by them, i.e. more immediate prevention and more savings. In the case under consideration, it can also be an *ex ante* renunciation of taking full advantage of future improvement of information. Through an early commitment to some conventions and rules of the game, an indirect arbitration of scientific controversies by non-scientific means is achieved. Here lies the analytical bridge between the two modes of existence of ^{S}PP previously depicted. Prudent agents and societies accept to pay a cost to reduce indecision generated by scientific uncertainty and the uncertain prospect of its resolution. For some, it may be more prevention today, or savings and transfer of resources to the future to increase adaptability. For others it may be investment in new technologies with the same purpose. For a last group it is an *ex ante* renunciation of the benefits of an improved information in the future, in favor of the benefits of an immediate strategic stabilization of public action to abate or eradicate potential hazards.

These findings raise questions about the best ways to reduce indecision under ^{S}PP, without losing the capability of making the best use of possibly improved information in the future. What may be called the corridor of precaution has to be found out in the middle of two threats of irreversibility: the one of physical phenomena driving to the potential hazard; the

[14] Here lies a specific social source of irreversibility: once a regulatory regime has been set up, investment strategies of agents are progressively re-organized around this regime. Regulatory regimes tend to be fixed in durable capital goods, creating a vested interest not to change the regime before an adequate amortizing of investments.

one of regulatory regimes and technological fixes that are poorly responsive to the evolution of scientific and technological knowledge.

3.2 Precautionary measures should depend on the nature of risks

One of the side results of Gollier *et al.* is that their 'precautionary effect' can be demonstrated to exist non ambiguously only under some assumptions about utility functions (concavity of the objective function in the distribution of probabilities) and types of risks (small risks and risks with two positions, low and large). This statement is useful in the debate about the generality to be given to the ^{S}PP. Within law research, some fellows are now ready to consider ^{S}PP as a general principle of law whatever the sector affected and the policy field (environment, public health, national military safety, …). In the same vein, the European Commission argued that the ^{S}PP has "*become a full-fledged and general principle of international law*"(EC [2000], p. 11), which is not accepted by other countries in the international arena, including the United States.

Other scholars consider that the ^{S}PP is only valuable for some sectors and some types of hazards, and that particular contents that it may have in specified contexts should be preserved from premature and undesirable extension. It is no secret that, while most scientists favour the ^{S}PP for key environmental issues, many specialists are reluctant to see that principle implemented for health issues. In that sector, the fear is that it would place physicians and public authorities under a double bind (Bourel [1998]; David [1998]): on the one hand an obligation to treat the sick or to take preventive initiatives for the safeguard of public health (vaccination); on the other hand, an obligation of prevention of potential dangers resulting from the treatment or prevention policies. This conflict typically arose in the case of hepatitis B vaccination programmes in France. Invoking the precautionary principle, a governmental decision suspended systematic vaccination programmes at school[15] because of potential risks of a scarce nervous pathology and in spite of rather established benefits for public health. Clearly, ^{S}PP cannot be implemented the same way in the field of public health as for environmental policies. It is not possible to let patient untreated and ask them to wait for the development of science in order to begin a treatment only when physicians are sure that it is absolutely safe and the most appropriate. Taking some unknown potential risks (exposition to new viruses through blood transfusion, for instance) is a regular condition of most treatments. The case of vaccination also illustrates the trade-off between private and public responsibilities in order to interpret the requirements of ^{S}PP in a given context; some decisions should be assigned to private agents once existing information is appropriately disseminated, whereas other decisions should remain in the hands of public decision-makers (see thereafter).

Even if the ^{S}PP becomes a general principle of public and civil law in some countries, it is quite important to specify its requirements in various policy fields and for various types of hazards. This is one major reason for which intermediate constructs are necessary between the general statement of the principle in laws and international statements, and concrete implementation by decentralised agents. If public authorities care to promote welfare and to avoid legal insecurity, it would not be wise for them to let the entire charge of elaborating

[15] Vaccination was systematic but not compulsory. Parents previously had the right not to expose their children to this vaccine.

specific contents to case law. As mentioned by French law 95-101 introducing the ^{S}PP in the domestic law system, this principle should "*inspire protection policies within the limits of laws that precise its significance*". Economic analysis could help to classify situations according to the different kinds of risks and utility functions.

3.3. Collective precautionary decisions and individual attitudes of prudence

Another result of Gollier *et al.* is that the existence of a precautionary effect critically depends on the shape of individual utility functions, characterising very 'prudent' agents. A straightforward conclusion is that it may exist for some agents and not for others. For private risks, these differences may contribute to the diversity of economic behaviours and feed some markets. For collective risks at national or international level, this situation raises a specific problem of the institutional procedures to determine collective choices. Without entering the debate about aggregation of preferences within a collective utility function, I want to stress the opposition between two approaches.

The first one, advocated by supporters of the thesis of a general and direct validity of the ^{S}PP for any private or public person (Boy [1999]) is that, independently from any existing regulatory framework, each agent is personally obliged to implement the ^{S}PP whenever his or her behaviour may generate potential hazards for other people or for the environment, now or in the future. Courts should watch the respect of such legal obligations and enforce them. Note that this issue is conceptually different from civil liability considerations. For any existing regime of strict liability, taking account of the ^{S}PP does not change anything. Such regimes do not refer to 'faults'; it is sufficient for the victims to prove the causal link between the damage and the risk-generating activity. All this happens *ex post*, once the damage has been achieved and checked, and is not concerned by *ex ante* attitudes but by the result.

The second one is that the ^{S}PP is, above all, a policy principle, the implementation of which belongs to the specific responsibility of public authorities. It generates a political accountability regarding both the organisation of a public order of precaution and appropriateness of public management decisions. Such responsibility and accountability could not be short-circuited by court interference without damage being done to the social balance that the ^{S}PP is supposed to set up (Godard [2001b]). Firstly governments have to take initiatives to supplement or elaborate a public framework of implementation of the ^{S}PP in various directions: targeted development of scientific knowledge by financing research programmes, organising public expertise, putting in place biological watch to look after unwanted ecological evolutions or epidemiological phenomena, developing public debates to enlighten what the socially accepted levels of potential dangers are and restore social trust in expertise. Secondly, governments should also take preventive measures to address given potential hazards on the basis of these various procedures. As it is asserted by the European Commission and the European Council [2000]), the final responsibility to define what are acceptable levels of potential risks should be considered as eminently political by nature, in relation with values of sovereignty and democracy.

This last position would mean that law courts should not be made judges of the substantial balance of decisions taken on the basis of ^{S}PP, within the limits covered by the notion of 'manifest error of appreciation', a classical concept of fault for public decisions. Within these limits, judges should care only of the adequate formal respect of legal procedures put in place. In that sense courts could assess the legality of given public acts based on the ^{S}PP (Cans [1999]), without interfering with the fine-tuning of ^{S}PP decisions.

How can the Gollier et al.'s result enlighten such issues? It may be seen in the following way. First, since different individual agents have different utility functions and different attitudes towards an increasing risk – not all are prudent -, spontaneous decentralised responses to a general obligation of ^{S}PP will presumably be very diverse across agents, since the latter will differently appreciate the requirement of proportionality of responses prescribed by the ^{S}PP. For collective risks, this uncoordinated diversity of responses is a source of damage to collective welfare, since some agents will rather carelessly contribute to alter the level of prevention or safety that other agents are trying to establish by paying a significantly higher price. This is typically a case of under-optimal Nash equilibrium in case of decentralised production of a public good. Secondly, there are good psychological and economic reasons to presume that the group of entrepreneurs having to take decisions involving the development and the dissemination of modern but controversial technologies such as GMOs or new drugs are in average less risk-adverse and less prudent than the remaining part of society:

- to be entrepreneurs, their psychology should be compatible with risk-taking;
- in contemporary industrialised societies their mean wealth level is superior to the wealth per capita of society, making most of them less adverse to loss of marginal income;
- competition by innovation pushes them to try to be the first to take a new market, and tends to erode incentives to take into account the subtleties of (quasi) option values and delaying investment until information about safety is asymptotic to certainty (Gollier and Treich [2001]).

Meanwhile, such entrepreneurs constitute a group that takes a leading role in generating new potential dangers for health and the environment in modern society by massively developing new technologies, products and activities. With that background, letting top management of firms decide which level of risk is acceptable for society within ^{S}PP will for sure involve a level of risk-taking that exceeds the one deemed acceptable by consumers and citizens.

For potential collective dangers touching the environment and public health, public authorities should have the responsibility to set the framework and establish trade-offs on levels of socially acceptable risk for a given class of hazard. But if their political accountability has to be respected, the right to take precautionary measures is linked to the seriousness of effort to settle a public order of precaution. Anyway, to bet on a decentralisation of judgements and initiatives in that matter, without appropriate and strong mechanisms of co-ordination, would only produce cacophony, a loss of social bearings and a waste of resources[16].

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[16] As a matter of fact, the new French Charter of the environment, which has been integrated in the Constitution of France in March 2005, includes an article about the PP that explicitly attributes the charge of implementing the PP to public authorities that are asked to watch that risks evaluation is undertaken and provisional and proportionate measures are taken.

3.4. Hysteresis and asymmetry of precautionary measures before and after commitment to a potential hazard-generating activity

Aside with the precautionary effect, Gollier *et al.* confirm previous analysis about the irreversibility effect: prospect of an increasing exogenous information gives a premium to initial choices that preserve future options, i.e. reversible options. In concrete settings, we can distinguish fundamental irreversibility of some physical transformations or losses, like the dying-out of a species, or the change of global climate, and more limited technological and economic irreversibility bounded to some time-horizon. In investment theory, the concept of sunk costs has been introduced to reflect this second type of relative irreversibility. Taking sunk costs into account introduces an asymmetry of judgements according to when the judgement is made and to the date of commitment to an investment. Bernanke [1983] and Dixit [1989] have developed this asymmetry around the concepts of 'bad news' mostly considered *ex ante* and 'good news' mostly considered *ex post*. Here lies a source of hysteresis in the responses of investors to uncertain prospects. Before commitment, more attention is given to potential 'bad news', generating a tendency to delay decision to get improved information, while after commitment, the opposite tendency to look after 'good news' introduces delay to react to bad news by going out of business[17].

This analysis can be related to the debate about the burden of proof within ^{S}PP. For some observers (O'Riordan and Jordan [1995], the major change introduced by the ^{S}PP is the reversal of the burden of proof: before the ^{S}PP, those alleging a potential damage had to prove the existence and the cause of the hazard before public action could impose some prevention; after the ^{S}PP, some scholars say that promoters of new technologies and products have to prove the latter to be harmless before being authorised to use the technologies or put the products on the marketplace. Other scholars have contented that this interpretation of ^{S}PP was not justifiable regarding lessons of logic and epistemology of modern science. What is really new with ^{S}PP is the way of putting a distance between the rationale of public decision-making and the requirement of scientific proofs, whatever proof should be obtained: the proof of the existence of a hazard or the proof of its non-existence (Godard [1997a and b], [1999]). So what is to be reversed is certainly not the burden of scientific proof of harmlessness, but the burden of proving that agents have done what they were obliged to, for instance making a series of predefined tests. Nevertheless, this conclusion, as it is, does not resolve the practical issue of who should bear the responsibility of bringing the scientific elements required to assess a potential hazard.

Interestingly, the European Commission refused to adopt a one-sided position on this assignment issue and granted the necessity to define these obligations in relation to already existing prior approval regimes. When et where countries have settled prior authorisation to gain access to the market (drugs, chemical products, etc.) it is logical to consider those products as potentially dangerous until business brings the scientific elements showing that safety is secured under existing knowledge and testing procedures, and that potential hazards are acceptable. When and where such a procedure is not in place, or products are already on the marketplace as a result of previous authorisation, it may be up to users and public

[17] This model can explain cases of prudence before investment, but it does not consider the implications of competition games in which there is a strategic gain to be the first on a specific new market. In that case, firms having already invested in the R and D pertinent to the business urge on an early introduction of their new technologies.

authorities to bring required scientific elements. They have to show that updated scientific information on potential hazards suggests that risk levels may not be acceptable and specific precautionary measures should be taken. But the Commission added: "*Action taken under the head of the precautionary principle must in certain cases include a clause reversing the burden of proof and placing it on the producer, manufacturer or importer, but such an obligation cannot be systematically entertained as a general principle. This possibility should be examined on a case-by-case basis* (…)". How to decide on this case-by-case assignment? Clearly respective capacities to bring required elements are important, as is the preservation of transparency and confidence in expertise[18]. But the burden sharing, among different agents (producers, consumers, public authorities), of sunk costs associated with the development of a given activity or technology is also an important feature. If a public procedure has already authorised them in the recent past, it may have created moral rights. In any case, banning a product after an authorisation was previously given will prejudice those agents who had decided to invest when they had taken the rules of the previous public regime for granted. Sunk costs install an asymmetry in situations before and after a collective commitment to a hazard-generating technology was made.

Therefore, new products and technologies could legitimately be controlled by rules that are different from those applied to the technology in use and products that are already disseminated on the market because of the weight of sunk costs and of relative irreversibility of commitments that are borne in one case and not yet in the other. To this regard the principles of comparison and coherence (treating similar hazards the same way) can find a justified limit, in spite of apparent irrationality (why impose GMO tests and screening that traditional agricultural techniques did not and would not pass?).

This conclusion could also cast some light on the choice of the moment public authorities should interfere with the development of activities or technologies potentially generating serious hazards to health and the environment. An early interaction could help avoid excessive sunk costs in the research and development of new technologies deemed unacceptable in a later phase of their course. Business may be inclined to share information about those developments in progress if the counterpart of accepting such a public precautionary scrutiny and follow-up would mean a lower chance of being exposed to stringent measures *ex post*, since the different sequences of development would be regularly scrutinised by a public authority.

4. Conclusions

The paper is based on the matching of concepts coming from two horizons: an economic theory approach of the precautionary principle framed in a Bayesian framework, ^{B}PP, and social heuristic concepts validated by public European institutions to interpret its requirements, ^{S}PP. This comparison is achieved by taking the model of Gollier *et al.* [2000] as

[18] Within debates about the implementation of ^{S}PP, it is sometimes suggested to organize scientific expertise as an adversarial process, like in lawsuits. This should be explored, without forgetting that a generalization of advocacy expertise in an unbalanced setting has contributed in the past to the discredit of scientific expertise, accused to serve only interest of big business. Protecting the independence of expertise may necessitate the creation of collective funds or other interfaces able to stop suspicion of capture of expertise through the financing channel. Another option would be to allocate public funds to some less-affluent stakeholders whose action is motivated by general interest in order to allow them to develop their own expertise.

a good representative of the most recent mainstream economic concepts about PP. It has been shown that, although they share some features (PP aims at scientifically uncertain hazards, the problem is framed as a dynamic sequential one, hazards are endogenous, in the sense that future levels of magnitude of potential damages depend on actions in previous periods), ^{B}PP and ^{S}PP differ a lot:

- ^{S}PP is distinguished from standard prevention by the opposition between potential dangers, the existence of which has not been scientifically established, and ascertained risks, for which objective probabilities can be defined and used for risk management. ^{B}PP is based on the distinction between risks with future improvement of information and risks without such an improvement;
- ^{B}PP is defined for an individual decision-maker in a Bayesian framework, while ^{S}PP aims at public decisions regarding collective risks. As such this does not invalidate ^{B}PP, but the latter is of no use to address the specific issue of collective decision-making under scientific uncertainty and controversies: how to elaborate common references and justified assessments and measures about the content of precautionary measures and determine the level of acceptable and accepted risk, when the resources of objectivity can no longer impose a common reality to all?
- ^{B}PP is defined as more prevention in the short run than otherwise, while ^{S}PP is defined as having prevention instead of no prevention at all, in spite of the lack of certainty about the existence of a danger; at the same time, ^{S}PP requires measures to be proportional and ^{B}PP shows a rather specific direction for interpreting this requirement, i.e. requiring stronger preventive action for more uncertain prospects, whereas the more general relationship accepted by the ^{S}PP doctrine is that the less scientifically plausible a potential hazard is, the less strong preventive measures should be (scientific watch and research instead of forbidding);
- ^{B}PP is conceived as a provisional means of managing the wait of an improved information allowed by scientific progress, while ^{S}PP is focused on early prevention because of the threats of irreversible losses or changes; the first one does not exist without the prospect of an improving information, while the second is not dependent on such a progress, without systematically denying its usefulness.

Beyond this comparison, some complements to ^{B}PP are suggested from ^{S}PP regarding the relationship with the concept of improving information. Several directions are suggested:

(1) The development of scientific activities is not to be confused with systematically improved information: prospects of surprises or absence of discoveries, of long-lasting indecidability of variables that are critical for precautionary strategies, of alternative phases of convergence and divergence of results from models, all contribute to establish scientific development as a circumstance of increasing *ex ante* uncertainty for reasons different from the precautionary effect of Gollier *et al.*

(2) What really matters is the contribution of scientific uncertainty to *ex ante* indecision and incapacity to plan action beyond short-term horizon. A description of scientific states of knowledge on potential hazards should catch *parameter uncertainty*, *informativeness*, *observability*, *plausibility*, *promise* and *relevance*.

(3) For some classes of hazards, information is not purely exogenous: it is necessary to commit to risky actions, in a controlled way, just to know more about the reality of benefits and hazards. This leads to an understanding of risky actions as scientific experiments conceived and used to provide informational feed back for the precautionary regime.

(4) The Bayesian assumption that it is always possible for agents to have subjective probabilities is not confirmed by the practical running of public expertise for complex hazards; a full quantitative risk assessment is deemed impossible in contexts requiring for the ^{S}PP.

(5) Finally, some experts and social groups see the ^{S}PP as a protection against failures and limitations of scientific method. This gives rise to two different modes of existence of the ^{S}PP: the first one manages the wait for improved information with provisional measures, oriented by the prospect of taking more adapted actions in due time; the second one aims at implementing a long term programme of reduction or eradication of all potential sources of potential damages, without being excessively concerned by scientific developments to come.

A third contribution of the paper is to explore the contribution that may be gained from economic and decision theory to get insights on how to interpret and implement ^{S}PP.

(1) ^{B}PP understands precaution as a means to respond to an increased *ex ante* uncertainty. It reveals the price that prudent agents are willing to pay to reduce uncertainty. Empirical studies on the forest decay in Germany and Europe have shown the existence of another response to the same problem: not more prevention, but prevention measures that stabilise new rules of the game for economic agents and indirectly impute the causes of a damage to some factors (SO_2 emissions from power stations or from cars, in this case), on the basis of available technologies; this other solution comes down to an *ex ante* renunciation of taking full advantage of a future improvement of information and confirms the price that agents are willing to pay to reduce *ex ante* uncertainty and their incapacity to plan action. This uncertainty aversion also explains the influence of the second mode of existence of ^{S}PP, the 'strategic' one.

(2) ^{B}PP shows that the 'precautionary effect' is not confirmed in any context, but depends on the nature of risks. This should refrain the tendency to see in the ^{S}PP a general principle of law valid for every situation marked by uncertainty. Even so, it would be quite important to elaborate specific clarification of ^{S}PP requirements in defined contexts.

(3) ^{B}PP also depends on the shape of individual utility functions. The 'precautionary effect' may exist for some agents and not for others. For collective risks, it is important for the collective welfare that public authorities set a common framework of action without letting each agent interpret the ^{S}PP on the basis of his/her own attitude to risk (aversion level) and ambiguity. Meanwhile it is contended by some law scholars that the ^{S}PP is already a legal norm that directly generates obligations for each economic agent and each citizen independently from the existence of an explicit regulatory framework. Political and economic thinking tells us that this thesis should not be considered favourably. Tackling potential hazards with the ^{S}PP in a reasonable, proportional and efficient way should entail public authorities to define explicit regulatory means adapted to the nature of potential hazards, and shape common procedures in order to organise research,

expertise, information of the public and public debate. What is at stake is to find the accepted social process in charge to define the acceptable levels of potential hazards.

(4) One implication of irreversibility in the field of business investment is the existence of sunk costs. They lead to an asymmetry in the way investors grant information about future prospects according to their stance before commitment or after. Here lies a source of hysteresis in investment. This view can be related to the debate about the assignment of the burden of bringing required scientific information on potential hazards generated by a product or a technology. It is justified to refuse, as the European Commission does, a one-sided general rule on that matter, since it should depend on how products and technology are positioned before or after the test of formal social acceptation: products already on the marketplace should not be treated the same way as new products, since the former have already been accepted and a lot of actors (producers, retailers, users) have committed themselves to their development and use; products and technologies already submitted to a prior approval regime should not be treated the same way (they should bear the burden) as those that are not (the burden could legitimately be placed on the authorities). Although apparently contrary to the principle of coherence in risk management, asymmetry of requirements can be justified by the distribution of sunk costs, benefits and risks across society.

To sum up, this paper may be considered as a report of the relative autonomy of the development of economic theory on the one hand, and the shaping of reasoned social heuristic concepts for interpreting new social norms as the Precautionary Principle on the other hand. It is also a plea of the net value that both parties could extract from cross-fertilization, once the confusion between both developments is avoided. Social norms cannot be seen as a direct transcription of economic concepts, and economic concepts cannot be reduced to a direct extension of empirically shaped heuristics. Mutual adjustments of selected stylized facts are at the core of this cross-fertilization.

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