PRECAUTIONARY PRINCIPLE

The Precautionary Principle (PP) has its roots, some believe, in the German Democratic Socialism in the 1930s, centering on the concept of good household management (see, e.g., O'Riordan and Cameron 1994). A precursor of the PP is known to be the German principle of Vorsorge, or foresight, that was introduced in the early 1970s as an interventionist guideline for German environmental policy (Morris, 2000, Sunstein, 2005). It is often said that the PP was first applied in 1984 at the International Conference on Protection of the North Sea. Its popularity considerably increased after the Conference of Rio in 1992 in which principle 15 of Rio Declaration states "*Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation*". Similar definitions have been proposed in international statements of policy including the 1992 Convention on Climate Change, the 1992 Convention on Biological Diversity, the Maastricht Treaty in 1992/93, and the 2000 Cartagena Protocol on Biosafety. The PP has also been enacted in the national law of several countries, especially in Europe.

The PP is the most notable anticipatory principle with special relevance for human-induced environmental problems under conditions of scientific uncertainty. Although devoid of practical content, the main message of the PP is conceptually clear: the anticipation of scientific progress should not justify the delay of measures preventing environmental degradation. In practice, its scope has became wider and there are reasonable grounds for applying it to regulate the protection of human, animal and plant health issues (see, e.g., Commission of European Communities, 2000).

The economic analysis of the PP has mostly studied the tension between two effects: i) developing an economic activity that is profitable today but may pose risks to the society in the future, ii) not developing this activity until conclusive scientific information comes about its harmlessness. The PP is said to be socially efficient if the benefit of postponing the risky activity is larger than its cost. To put it differently, the PP is efficient if the net social benefit of early prevention efforts is positive. The economic conditions for efficiency were first analyzed in the 1970s, in the literature on the "irreversibility effect".

The "Irreversibility Effect"

Let us consider a model of economic decisions represented by the following optimisation program

$$\max_{x_1 \in D_1} E_{\tilde{y}} \max_{x_2 \in D(x_1)} E_{\tilde{\theta}/\tilde{y}} v(x_1, x_2, \tilde{\theta}) \quad (1)$$

The timing of the model is the following. At date 1, the decision-maker chooses x_1 in a set D_1. Between date 1 and date 2, he observes the realisation of a signal $\tilde{y}$ correlated to $\tilde{\theta}$. At date 2, before the realisation of $\tilde{\theta}$, he chooses x_2 in a set $D(x_1)$. Finally $\tilde{\theta}$ is realised and the decision-maker gets a utility payoff $v(x_1, x_2, \theta)$. The problem is to determine the effect of a "better information structure" $\tilde{y}$ on the optimal decision at date 1.

We first solve this problem when $v(x_1, x_2, \theta) = x_1 + x_2\theta$ with $D_1 = \{0,1\}$ and $D(x_1) = \{x_1, 1\}$. This special case can be interpreted as a simple investment problem. The development of a "risky" project - like the exploitation of a forest in which the value of biodiversity is unknown - is considered. If the project is implemented today (x_1=1), it yields a net benefit of 1 today and of $\tilde{\theta}$ in the future. The project is irreversible in the sense that once it is developed it cannot be stopped ($x_2 = 1$ if $x_1 = 1$). The stakeholders are assumed to be risk-neutral.

Consider first the case in which no scientific progress is expected, i.e. when $\tilde{y}$ is independent from $\tilde{\theta}$. In this case, program (1) becomes

$$\max_{x_1 \in \{0,1\}, x_2 \in \{x_1, 1\}} E_{\tilde{\theta}}(x_1 + x_2\tilde{\theta}) = \max(1 + E_{\tilde{\theta}}\tilde{\theta}, 0) \qquad (2)$$

The project is either implemented today if its expected net present value (ENPV) is positive, otherwise it is never implemented. This is the case when $1 + E_{\tilde{\theta}}\tilde{\theta} \geq 0$. Consider alternatively the case of scientific progress that yields perfect information about $\tilde{\theta}$. This is equivalent to assuming perfect correlation between $\tilde{y}$ and $\tilde{\theta}$. In this case, program (1) becomes

$$\max_{x_1 \in \{0,1\}} E_{\tilde{\theta}} \max_{x_2 \in \{x_1, 1\}} (x_1 + x_2\tilde{\theta}) = \max(1 + E_{\tilde{\theta}}\tilde{\theta}, E_{\tilde{\theta}} \max(0, \tilde{\theta})) \qquad (3)$$

Viewed from today, the ENPV of postponing the decision to develop the project equals $V = E_{\tilde{\theta}} \max(0, \tilde{\theta})$. The project will be initiated today only if it yields a larger ENPV than that obtained if the decision is postponed to the future: $1 + E_{\tilde{\theta}}\tilde{\theta} \geq V$. The quantity V has been coined the (quasi-)option value (Arrow and Fisher, 1974).

The comparison between (2) and (3) shows that scientific progress has the effect to increase the ENPV of the best alternative option from 0 to $V \geq 0$. Consistent with the PP, this example shows that the prospect of scientific progress may lead to postpone the development of the risky project. The prospect to receive information in the future increases the cost of choosing the irreversible decision today. This decision would prevent the decision maker from taking advantage of the information in the future. This is the "irreversibility effect" (Henry, 1974).

The literature has studied the generalization of this effect in several directions including partial resolution of uncertainty, relative flexibility, continuous decision variables, non-separable preferences and risk aversion. This example relied on two extreme information structures: one structure gives no information and the other gives perfect information. The appropriate general notion of a "better information structure" was introduced by Blackwell (1951). This general notion was used and developed in a systematic way by Epstein (1980) under some differentiability assumptions. Epstein then demonstrated that the "irreversibility effect" does not hold for most payoff functions $v(x_1, x_2, \theta)$. Jones and Ostroy (1984) have generalised Epstein's result to non-differentiable problems and to a more general characterization of adjustment costs.

The "Precautionary Effect"

The subsequent literature has mostly used the Epstein's approach to examine the effect of better information for various payoff functions, assuming continuous decisions, differentiability and that the conditions for optimisation in (1) were satisfied. Ulph and Ulph (1997) consider a payoff function of the form $v(x_1, x_2, \theta) = u_1(x_1) + u_2(x_2) - \theta d(\delta x_1 + x_2)$ and interpret x_t as the emissions of CO2 in period t and $\theta d(.)$ as the uncertain climate damage that depends on the sum of emissions up to a decay parameter δ. They show that a better information structure may lead to increase, and not decrease, emissions at date 1. Gollier, Jullien and Treich (2000) analyse a similar model with monetary damages $v(x_1, x_2, \theta) = u_1(x_1) + u_2(x_2 - \theta(\delta x_1 + x_2))$. They show that that emissions at date 1 decrease if and only if $u_2(.)$ has a constant relative risk aversion lower than 1, or a derivative "sufficiently" convex. This latter condition suggests that the coefficient of prudence (Kimball, 1990) is instrumental for signing the effect of a better information structure on x_1. This is not surprising since in this model x_1 affects future utility u_2, not anymore through a reduction of the future set of choices, but directly by changing the risk borne in the future $\theta(\delta x_1 + x_2)$. This is the "precautionary effect". Overall these results suggest that the qualitative effect of a better information structure strongly depends on functional forms, in particular on the risk attitude of the decision maker.

The "Ambiguity Aversion" Effect

The Ellsberg paradox tells us that many people do not behave according to the expected utility criterion when facing (scientific) uncertainty, contrary to what we assumed above. Gilboa and Schmeidler (1989) proposed an alternative decision criterion that performs better in this context. Under their model of ambiguity aversion, for each possible choice ex ante, the decision maker computes the expected utility conditional to each plausible scientific theory, and takes the minimum to evaluate the welfare generated by that choice. Agents who behave according to this maxmin model exhibit a form of choice-sensitive pessimism, which is called "ambiguity aversion". As shown for example by Chen and Epstein (2002) for financial markets, this ambiguity aversion reinforces risk aversion to induce people to adopt a more precautionary behaviour in the case of (scientific) uncertainty, as suggested by the PP.

Positive Aspects

The economic approach of the PP has been mostly normative so far. Under which conditions is the PP socially efficient? How should scientific uncertainty affect risk management? An equally important approach involves discussions on how the PP has been or should be implemented. We briefly turn to these more positive aspects.

A general argument is that scientific uncertainty may exacerbate, or even trigger, some market or regulatory failures (Gollier and Treich, 2003). In a global pollution problem such as climate change, there are incentives for countries to free-ride on other countries' reduction of emissions. Coalitions formations may reduce this inefficiency but coalitions are less likely to form if there is scientific progress (Na and Shin, 1998). At a political level, an argument used by goverments is that the problem is "too uncertain" to abate emissions. Early commitments may help, but there are incentives for some governments, once information reveals low damages in their own country, to refuse to abate emissions at a level announced by previous governments.

A difficult question is that of the most efficient policy to induce firms to internalize the risks they pose to the economy. In a market with imperfect legally enforceable property rights, firms may not take up the option of waiting for better information when they are high profits guaranteed to first-movers. How to set binding legal incentives for firms' past actions made under conditions scientific uncertainty is a big issue in law. This issue is augmented by the classical limited liability problem.

Another issue is that of international relations and the different approach to safety and precaution across countries (Hammitt et al., 2005). One possibility is to leave to the states the decision of how to account for scientific uncertainty in their safety policy. The problem is that such a discretionary power may be the source of disguised protectionism.

Scientific uncertainty may also increase the cognitive biases of the public in their perception of risks, like the standard "availability heuristic". Citizens often deem an event to be more probable when its occurence can be easily recalled or visualized. As a result, they may overreact to highly publicized risks. Interest groups may exploit this bias, as well as politicians. A critical interpretation of the PP is to view it as a demagogic response to citizens' perceptions of risks (Sunstein, 2005).

More generally, scientific uncertainty may favour, through the multiple channels of decision-making, opportunistic behaviours. Scientific uncertainty opens rooms for discretion in the risk regulatory process. Several social actors (entrepreneurs, lobbies, experts, politicians, media...) may take advantage of the lack of scientific evidence to promote their own interest. The PP may be viewed as a soft safe-guard against opportunistic behaviours in situations of asymmetric and evolving information. Yet, designing stronger mechanisms needs a more detailed analysis of the sources of market failures, of the risk management institutions and of the citizens' behavioral responses. This may explain part of the existing voluminous literature on the PP in social sciences, and may occupy economists in the future.

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