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# THE PRECAUTIONARY PRINCIPLE: WHAT IS IT, WHERE DID IT COME FROM, HOW SHOULD WE USE IT?

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# THE PRECAUTIONARY PRINCIPLE: WHAT IS IT, WHERE DID IT COME FROM, HOW SHOULD WE USE IT?

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***Since being globalized by inclusion in the 1980's and 1990's through several U.N. declarations and treaties, the Precautionary Principle has become a flashpoint internationally among scholars working in the fields of risk, international environmental law, European Union law and even U.S. federal law. The controversy surrounding the Precautionary Principle apparently arose and persists because the Principle is undertheorized. We revisit three fundamental questions: what is the Precautionary Principle, where did it come from, and how should we use it. Because the Precautionary Principle is a legal tool that is used internationally to manage technology, a comprehensive discussion of it is organically international and interdisciplinary. We argue that the Precautionary Principle is an index of formative measures of risk and fear; that its origins should be investigated specifically in relation to the particular legal instrument in question; and that it should be utilized only as an indicator of public perception and not as a prescriptive risk management tool. Because the Precautionary Principle is currently utilized internationally as a prescriptive tool, our recommendation is both controversial and non-trivial.***

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Keywords: Precautionary Principle; formative measures

## INTRODUCTION

The controversial Precautionary Principle is one answer to the question, "how should governments make decisions about (the fear of) uncertain risk about technology?" It answers that question in its enigmatic triple negative form, namely that the absence of rigorous proof of danger does not justify inaction (the non-preclusion Precautionary Principle; Stewart 2002). In practice, the slightly stronger and more substantive so-called weak form is usually invoked: the lack of scientific evidence does not preclude action if damage would otherwise be serious and irreversible (Mandel and Gathii 2006). The Precautionary Principle is particularly invoked in the commercialization of controversial new and emerging technologies that are widely considered to be characterized by unknown risk and uncertainty, such as nanotechnology (Stebbing 2009, Heselhaus 2010), genetically modified organisms (Giampietro 2002) and artificial intelligence (Clarke 2005). The Precautionary Principle is not an obscure legal concept. Rather, it appears in European legislation applicable to technology, viz. in Article 23 (the Safeguard clause) of Directive 2001/18/EC on the release of genetically modified organisms (GMO) at the European Community level; and Article 34 of Regulation no. 1829/2003 on the consumption of GMOs as food or feed; and it has been invoked in technology cases before the European Court of Justice (Rogers 2011), such as in cases relating to food safety (Sadeleer 2006), plant fungicide (ECJ 2010), and the legal status of food containing trace amounts of genetically-modified DNA (ECJ 2011). And at least one researcher has argued that the Precautionary Principle appeared in U.S. legislation and related case law starting in 1970 (Ashford 2007: 354, 361).

Since being globalized by inclusion in the 1980's and 1990's through several U.N. declarations and treaties, the Precautionary Principle has become a flashpoint internationally among scholars working in the fields of risk, international environmental law, European Union law and even U.S. federal law. On the one hand, the Precautionary Principle has been called a widespread guide to action in modern society (Furedi and Derbyshire 1997, Tudor 2003).

On the other hand, it has been called incoherent (Peterson 2006), unprincipled (Marchant 2001) and even dangerous (Sunstein 2002). It has also been asserted that it does not matter whether the Precautionary Principle is incoherent, because the relevant question is whether there are contexts in which it makes sense to use it (Dana 2009). A consensus has not been reached. Yet before being adopted, proposed new legal principles, rules and rights are usually rigorously discussed and tested. Plaintiffs bring novel cases in local courts, legal scholars argue positions through articles and amicus briefs. These proceedings can take decades. The judicial history of the U.S. Supreme Court 2015 decision on same-sex marriage (*Obergefell* et al. *v Hodges, Director, Ohio Department of Health, et al.,* 576 U.S. (2015)) can be traced back to 1970 (Frost 2015). The same procedure applies to positive international law or treaties. It took the United Nation's International Law Commission (ILC) more than twenty years to adopt in 1994 a set of thirty-three draft articles on the Law of the Non-Navigational Uses of International Watercourses (Arcari 1997). To complement that work, in 2008 the ILC issued nineteen draft articles on transboundary aquifers (McCaffrey 2009). It is true that the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses is a codification of customary international law; and it is true that international law does not require a minimum duration of time for custom to ripen into law. But it still took the ILC and the international community more than twenty years to codify the customary law into positive law; and because the Precautionary Principle appears in treaties and statutes, we are concerned here with the process of making positive international law. Some have argued that the Precautionary Principle is part of customary international law (Cameron and Abouchar 1991, McIntyre and Mosedale 1997), but that is a minority position (Bodansky 1991, 1995).

The problem with the Precautionary Principle is, none of this ever happened. Somehow it managed to get into one international treaty, then another, then another. Precautionary thinking bubbled up in American federal legislation (Wagner 2000, Ashford 2007) and, as we argue below, federal common law. Unease about the Precautionary Principle can be succinctly summarized: it is undertheorized, and that deficiency is amplified by its growing use in international, regional and national law. As with any other legal principle, we still need to understand its fundamental theoretical underpinnings, viz. its origin and place in law and society, and its ontology and epistemology as both a legal principle and more generally as a form of innovation or new information.

In the present article we take a fresh look at the Precautionary Principle, with the intent of revisiting three fundamental questions: what is it, where did it come from, and how should we use it. While we are aware that the answers to these three questions may appear to some as only loosely related, we assert that the questions themselves are tightly related. The three questions are also interdependent: we should manage technologies only with legal principles that we fully understand. Moreover, since the Precautionary Principle is a legal tool that is used to manage technology, a comprehensive discussion of it is inescapably interdisciplinary.

The present research lies at the confluence of risk management, psychometrics and sociology; international, regional and national law; formative measures; philosophy; and the history of mathematics. The present article should be of interest to those studying and applying the Precautionary Principle in legislative, judicial, regulatory and policy contexts. It should also be of interest to those working in the risk management field, as well as to anthropologists studying the ethnology of risk and fear. It may also interest sociologists studying the so-called rise of the risk culture.

## THE PRECAUTIONARY PRINCIPLE: WHAT IS IT?

It has been asserted that uncertainty frames the Precautionary Principle (Francot-Timmermans and De Vries 2013). It has also been asserted that the Precautionary Principle is "based on fear of uncertainty" (Barnard and Morgan 2000: 112). We think both positions are correct. To illustrate we turn to Slovic's (1987) seminal psychometric study on the perception of risk.

Slovic (1987) showed that lay people do not view risk in the same way that experts view risk. Whereas experts view risk as an index of associated estimated annual fatality, lay people view risk as comprising other hazard characteristics (Slovic 1987: 283). Slovic's (1987) psychometrics study parsed risk into two principal components. The first principal component, "dread risk," comprised hazards that were associated with perceived lack of control, dread (great fear or apprehension), catastrophic potential, fatal consequences, and the inequitable distribution of risks and benefits. This component was associated with, for example, nuclear technology. The second component, "unknown risk," comprised hazards that were considered to be unobservable, unknown, new, and having delayed effects. This component was associated with, for example, chemical technologies.

There is an apparent resonance between Slovic's (1987) study and the Precautionary Principle. According, for example, to Todt and Luján (2014: 2164), the Precautionary Principle is meant to be invoked "whenever there are reasonable indications of possible important (highly damaging, irreversible, systemic, etc.) impacts on human health and the environment, even in the face of inconclusive data, lacunae in scientific knowledge, and doubts about the respective cause-and-effect relationships." Slovic's dread risk (perceived lack of control, dread, catastrophic potential, fatal consequences) maps onto Todt and Luján's "possible important (highly damaging, irreversible, systemic, etc.) impacts on human health and the environment." Slovic's unknown risk (unobservable, unknown, new, and having delayed effects) maps onto Todt and Luján's "inconclusive data, lacunae in scientific knowledge, and doubts about the respective cause-and-effect relationships" (Fig. 1). Similarly, Slovic's (1987) risk components can also be mapped onto Sandin's (1999) dimensions of the Precautionary Principle. Sandin (1999) recast the Precautionary Principle in four so-called dimensions: *if* there is (1) a threat, which is (2) uncertain, *then* (3) some kind of action (4) is mandatory. Dread risk relates to the threat dimension, and unknown risk relates to the uncertain dimension (Fig. 2).

| Slovic's Risk Components | | Todt and Luján's Precautionary Principle Definition |
|---|---|---|
| Dread risk | → | possible important impacts on human health and the environment |
| Unknown risk | → | inconclusive data, lacunae in scientific knowledge, doubts about cause-effect |

**Fig 1. Mapping of Slovic's (1987) risk components onto Todt and Luján's (2014) definition of the Precautionary Principle.**

| Slovic's Risk Components | | Sandin's Precautionary Principle Dimensions |
|---|---|---|
| Dread risk | → | the Threat dimension (ontological) |
| Unknown risk | → | the Uncertain dimension (epistemological) |
| | | the Action dimension |
| | | the Command dimension |

**Fig 2. Mapping of Slovic's (1987) risk components onto Sandin's (1999) dimensions of the Precautionary Principle.**

These mappings show that the Precautionary Principle is a layperson's approach to risk management. Stated in terms of Slovic's (1987) psychometrics, the Precautionary Principle tells judges, law-makers, policy makers, etc., that the layperson's perception (i.e., the public's perception) that something comprises an unknown risk is an

acceptable reason for taking protective action. The Precautionary Principle apparently validates unknown risk as a motivation for governmental decision making. It apparently equalizes unknown risk with dread risk.

But the Precautionary Principle conflates risk-sensu-experts and risk-sensu-laypersons; thus these mappings also show that the Precautionary Principle is animated not only by risk but also by fear, because risk-sensu-laypersons comprises (in part) fear. Dread risk, as previously mentioned, comprises dread, a form of fear. Unknown risk comprises hazards considered to be unobservable, unknown, new, and having delayed effects. It is likely not a controversial statement to say that laypersons consider these unknown risks to be hazards because they fear them.

Sandin (1999: 892) also asserted that "the threat dimension concerns ontology, the uncertainty dimension concerns epistemology"; thus the mapping of Slovic's (1987) risk components onto Sandin's (1999) dimensions of the Precautionary Principle shows us that the Precautionary Principle comprises both ontological and epistemological components. The Precautionary Principle's epistemology (Aven 2011, Carter and Peterson 2015, Steglich-Petersen 2015, Carter and Peterson 2016) and ontology (Aven 2011) both have been studied. These philosophical investigations, while valuable, do not relate to the present discussion of psychometrics.

The preceding investigations uncovered the bifurcated onto-epistemic nature of the Precautionary Principle, as having a risk component and a fear (and/or fear of uncertainty) component. The Precautionary Principle expresses public fear. But to express public fear, first it must measure it. This leads us to consider formative measures.

**Formative Measure of Risk and Fear**

Researchers often seek to operationalize the Precautionary Principle by substituting specific terms for its general terms (e.g., Sandin 1999: 898), that is, by transforming the legal principle into a legal rule; but this is an overly simplistic approach to legal principles. Legal principles have far broader and deeper functions. It has been stated that "[p]rinciples differ from rules in the sense that rules can be more easily directly applied in individual cases, while principles give a general direction for a decision" (Verschuuren 2006: 237). This definition of principle adequately characterizes the Precautionary Principle. The Precautionary Principle gives a general direction for a decision. It does not provide a template for substantive legal or scientific rule by which cases are adjudicated. It does not provide a template for a legal process. Principles "set the goals that have to be reached with (new) laws" (Verschuuren 2006: 238). What is the goal of the Precautionary Principle? To cause proactive measures to be taken, even in the face of uncertainty. It gives license to a decision maker to prescribe proactive measures in the face of uncertain but possibly substantial risk (Rogers 2011). It gives a decision maker license to measure the relevant fear of uncertainty, possessed by his constituents, that relates to the technology in question; and then to prescribe actions that are commensurate, not to the risk but to the fear.

What is underlying the Precautionary Principle is an index of formative measures that concretizes not only public perceptions of risk-sensu-experts but also public fear of uncertainty arising from the technology in question. Like other indexes, it comprises a plurality of formative measures, independent variables that interact with one another to form a single organic or organic-like entity (vis-a-vis a mere aggregate). The formative measurement model is

$$\eta = \sum \gamma_i x_i + \zeta, \; i = 1 \text{ to } n,$$

where $\gamma_i$ is the contribution of $x_i$ to the latent construct $\eta$ and $\zeta$ is the residual, such that the latent constructs are functions of the observables (Howell et al. 2007). The latent construct $\eta$ is also called an index. Formative measurement models were introduced to applied statistics in 1962 (Curtis and Jackson 1962), but economists have been constructing indexes (index numbers) since the beginning of the Nineteenth Century (Boumans 2001).

The fundamental issue with indexes is the correspondence between theoretical concept and measurable phenomena (Hansen and Lucas 1984: 24). This invites what Zimmermann (2007: 51) calls an onto-epistemic inquiry, which requires a researcher to "visualize physical properties of systems (and hence also biological properties) as a

result of human cognition which is initializing the modeling in the first place and defines some sort of specific disposition with respect to the world." In other words, your choice of model determines how you perceive the world, and the world determines your choice of models. Because we aggregate components into indexes, the world seems to us to be full of indexes; and we construct indexes because their components appear to us to synergistically comprise organic unities.

The value of identifying the Precautionary Principle as an index of formative measures is that it allows us to characterize and address the criticisms of the Precautionary Principle in a philosophically fundamental way. We use "index" to refer to measures comprising formative indicators (Diamantopoulos and Siguaw 2006). The Precautionary Principle has been said to be incoherent (Peterson 2006) but still rational to use it in certain policy contexts (Dana 2009). Similar criticisms and positive statements have been made regarding indexes of formative measures, e.g., economic index numbers have been supported as pragmatic compromises (Boumans 2001), but they have also been criticized as being not theoretically sound (Edwards 2010). These opposing positions have not been reconciled, but their separate reference frames have been identified (Boumans 2001); and as any mathematician or physical scientist will tell you, once reference frames have been identified, it is often possible to find a way to translate from one to the other. The reference frame of the critics of formative measures is the Axiomatization Movement.

**The Axiomatization Movement**

Indexes of formative measures are interpreted in two ways, according to respective schools of thought. The instrumental school of Fisher treats indexes as if they were empirical objects, and the axiomatic school treats indexes as formal axiom-based abstractions (Boumans 2001: 35). Under the instrumental approach, indexes such as the Precautionary Principle have an ontology because they exist separately from our ideas about them. Under the axiomatic approach, indexes have only an epistemology.

The Axiomatization Movement began with Pasch's (2013 [1882]) publication in 1882 of *Vorlesungen über neuere Geometrie*, in which he advocated grounding Euclidean geometry in more precise primitive notions and axioms. David Hilbert actually grounded Euclidean geometry in his own set of axioms in his *Grundlagen der Geometrie* (Hilbert 1899, 1902). He later discussed the broader intention of his program (Hilbert 1918); viz. that the axiomatic method will eventually render all of science subject to the mathematical method, which is important because he often said that every mathematical problem can be solved (Stöltzner 2015: 16).

The lack of axiomatization is now seen by proponents of axiomatization as indicating a lack of rigor (Boumans 2001: 315). Yet Hilbert's program was more pragmatic (Peckhaus 2003). He spoke in an architectural metaphor, stating that his intent was to provide a method for a "deepening of foundations" (Peckhaus 2003: 145) where foundations were in question, thus enabling continued development of theory and system. Hilbert might have been chagrined to see that his attempts to provide sound logical foundations had the effect of sacrificing pragmatic empirical adequacy and relation to reality for logical consistency. The solution to this paradox lies in the life work of Fisher, who pragmatically sought compromises between incompatible requirements (Boumans 2001), i.e., not everything is a theory, so not everything should be assessed as a theory.

**Other Risk Indexes of Formative Measures**

The Precautionary Index is not the only risk index of formative measures, and something may be learned from other risk indexes. Slovic's (1987) psychometric study treated risk as an index comprising formative measures. Rather than asking whether fear reflects certain symptoms such as anxiety, etc., Slovic sought participant responses to hazards. He used hazards as independent variables to a function comprising participant's reactions to those hazards (Fig. 3). These components comprise formative measures. As such they are indexes. More recently, Siegrist et al. (2005) applied the cognitive maps of hazard perceptions to data taken from individuals rather than to data of aggregated individuals. They verified that the two components also manifest in individuals, but they found variability

in component loadings (for example, some individuals scored high on one component and low on the other); and that these variations were correlated with general trust and general confidence, where general trust is the belief that other people can be relied on and general confidence is the conviction that everything is under control, and uncertainty is low. General trust and general confidence apparently were also formative measures. It is not surprising that an index comprises a distribution rather than a single number. Stochastic index numbers are based on the assumption than indexes have distributions (Clements and Izan 1987). A more precise deployment of the Precautionary Principle, if feasible, would be based on a distribution of individual responses rather than a single index number calculated from aggregated data.

Risk Index y = f (Hazards: Nuclear, Coal, Pollution, Biotechnology, Nanotechnology, Chemicals, etc.)

**Fig. 3. Hazards as formative measures for a Risk Index.**

Finance provides us with a fear index of formative measures. The Chicago Board Options Exchange Volatility Index (VIX) has been called a proxy for investor sentiment where high values indicate that investors are fearful about future performance of the U.S. stock market (Escueda et al. 2015). "The CBOE Volatility Index® (VIX)® is based on the S&P 500® Index (SPX), the core index for U.S. equities, and estimates expected volatility by averaging the weighted prices of SPX puts and calls over a wide range of strike prices" (CBOE 2016 [webpage]). The publishing of indexes of public precautionary sentiment may prove to be a useful risk management tool.

Another risk index of formative measures is risk factor epidemiology. In risk factor epidemiology, "various characteristics, including not only environmental variables but also physiological variables, habits, lifestyle, and so on, have been conceptualized as 'risk factors' for diseases" (Giroux 2015: 181). These "risk factors" are formative measures and "risk for disease" is their index. Criticisms of epidemiology resonate with those of formative measures, e.g., "the past 30 years of risk factor epidemiology have also presented us with a baffling and almost endless array of potentially causal observations" (Keyes and Galea 2015: 305); and "[a]s there are no underlying hypotheses for this kind of 'research,' beyond a general feeling that 'diseases of civilization' are caused by civilization, the method is based on 'stabs in the dark' (in Savitz's terminology)" (Skrabanek 1994: 553, referring to Savitz 1994). This epidemiology would be more scientifically defensible if it were used in conjunction with the experimental method of hypothesis formation and testing. As it stands, epidemiology and other formative measure-based activities have more the look of creative expression than scientific investigation.

## THE PRECAUTIONARY PRINCIPLE: WHERE DID IT COME FROM?

The Precautionary Principle is often said to have sprung from German environmental law like Athena from Zeus' forehead. We will now show that it precautionary thinking appeared even earlier, at least 1953, in the U.S. federal common law equitable remedy of the preliminary injunction; and that it makes more sense to research the appearance of precautionary thinking in separate disciplines, as an indication of a widespread cultural movement (Hanekamp et al. 2005), rather than searching for a single origin. Along these lines, we are not saying that German law or international law descended from the American preliminary injunction. Rather, we are looking for strong precautionary thinking in modern law that preceded the German law, only to show that the German law was not the first. Neither are we saying that the standard preliminary injunction illustrates strong precautionary thinking. Instead we are showing the failure of a modern attempt to expand the standard preliminary injunction to encompass strong precautionary thinking. Moreover, to be clear and to not overstate our case, we use the term "precautionary thinking" to refer to legal principles that resemble the Precautionary Principle but that are not specifically referred to as the

Precautionary Principle. The Precautionary Principle is often said to have first appeared in the guise of the *Vorsorgeprinzip* (foresight principle) in the 1970 German water protection law (Boehmer-Christiansen 1994, Raffensperger and Tickner 1999). It Precautionary thinking also appeared around that time in Sweden's 1973 Act on Products Hazardous to Man or the Environment (Wahlström 1999). Why is the origin of the Precautionary Principle attributed by some to German law rather than to Swedish law? It has been noted that the Germans were the first to introduce precautionary thinking into an international declaration (McIntyre and Mosedale 1997). That early advocacy may have endowed Germany with the appearance of authoring the Principle.

What has hitherto escaped notice is appearance of precautionary thinking in the U.S. federal common law preliminary injunction. A preliminary injunction restrains a party from going ahead with a course of conduct or compelling a party to continue with a course of conduct until the case has been decided. According to the U.S. Supreme Court (*Winter v. NRDC, Inc.*, 129 Sup.Ct. 365, 374 (2008)), "A plaintiff seeking a preliminary injunction must establish that he is likely to succeed on the merits, that he is likely to suffer irreparable harm in the absence of preliminary relief, that the balance of equities tips in his favor, and that an injunction is in the public interest." This legal standard resonates with the aforementioned so-called weak form of the Precautionary Principle, which states that the lack of scientific evidence does not preclude action if damage would otherwise be serious and irreversible. The preliminary injunction dates back to at least the eighteenth century (Leubsdorf 1978); but that does not suggest an eighteenth century origin of the Precautionary Principle, because there is a critical difference between the two. The preliminary injunction requires a showing by the plaintiff that he or she is likely to succeed on the merits. The Precautionary Principle requires no such showing. However, an attempt was recently made to make the preliminary injunction more precautionary, and that attempt failed.

The Ninth Circuit United States Court of Appeals attempted to expand the federal preliminary injunction to protect plaintiffs seeking protection from possibility of irreparable harm, but In *Winter v. NRDC* the U.S. Supreme Court struck it down (Bates 2011). The Ninth Circuit was issuing preliminary injunctions on only the *possibility* of irreparable harm to the plaintiff; they did not require plaintiff to show the *likelihood* of irreparable harm. The Supreme Court held that "Issuing a preliminary injunction based only on a possibility of irreparable harm is inconsistent with our characterization of injunctive relief as an extraordinary remedy that may only be awarded upon a clear showing that the plaintiff is entitled to such relief" (*Winter v. NRDC, Inc.*, 129 Sup.Ct. at 375-76). We traced the origins of the Ninth Circuit's "possibility of irreparable harm" test to at least their 1975 decision, W*illiam Inglis & Sons Baking Co. v. ITT Continental Baking Co., Inc.,* 526 F.2d 86 (C.A.9 (Cal.), 1975); that decision cited an earlier Ninth Circuit decision from 1972, *Costandi v. AAMCO Automatic Transmissions, Inc.*, 456 F.2d 941 (9th Cir., 1972), but the language in the 1972 decision is not as clear as the language in the 1975 decision. In the 1975 case the Ninth Circuit also cited two Second Circuit decisions from 1970 and 1953. The 1953 decision reads "To justify a temporary injunction it is not necessary that the plaintiff's right to a final decision, after a trial, be absolutely certain, wholly without doubt; if the other elements are present (i. e., the balance of hardships tips decidedly toward plaintiff), it will ordinarily be enough that the plaintiff has raised questions going to the merits so serious, substantial, difficult and doubtful, as to make them a fair ground for litigation and thus for more deliberate investigation," *Hamilton Watch Co. v. Benrus Watch Co.*, 206 F.2d 738, 740 (2 Cir. 1953). To this the judge makes several citations, but it is not necessary to trace the rule back further. We have shown that it pre-dates the 1970 German water protection law. The significance of the Ninth Circuit's Preliminary Injunction jurisprudence (i.e., based on only the *possibility* of irreparable harm) suggests that the attempt to identify a single origin of the Precautionary Principle is misguided. It pre-dates the rise of the risk society (Beck 1992), which allegedly characterizes "late modernity" beginning circa 1960.

It is also notable that the Supreme Court has not ruled on a related precautionary practice, one that it is currently used by the Ninth Circuit Court and also by other federal Courts of Appeals. This is the so-called sliding scale/serious question test for preliminary injunction applications. This test states that a stronger showing on one element of the preliminary injunction may offset a weaker showing on a different element, e.g., a stronger showing of irreparable harm to a plaintiff might offset a lesser showing of likelihood of success on the merits. The serious question

test is a narrow slice of the sliding scale test: a preliminary injunction will issue if serious questions going to the merits were raised (i.e., in favor of plaintiff; plaintiff presented a plausible case) and the balance of hardships also tips sharply in the plaintiff's favor (*Alliance for the Wild Rockies v. Cottrell*, 632 F.3d 1127, 1131-32 (9th Cir. 2011)). In contrast to the Ninth Circuit's practice that was overturned in *Winter v. NRDC*, which relates to harm (a plaintiff need show only the possibility of irreparable harm), the serious question test turns on the plausibility of plaintiff's case and the balance of hardships. This type of approach has been distinguished from the Precautionary Principle, as a "precautionary approach" (Barnard and Morgan 2000: 116).

So where did precautionary thinking, and the Precautionary Principle come from? The question is likely too vague and broad. It is more scholarly and less mystical to ask how it came to be in a specific legal instrument. For American legislation we would turn to the Congressional Record. For international treaties we would turn to the travaux préparatoires. Sociological explanations such as the risk society may help explain the diffusion of the innovation but they do not help explain its origin.

## THE PRECAUTIONARY PRINCIPLE: HOW SHOULD WE USE IT?

Epidemiological risk factors and other formative measures are criticized as stabs in the dark having no underlying hypotheses (e.g., Skrabanek 1994); but stabs in the dark can have value if their energy is directed. What is missing from the practice of indexes of formative measures is a disciplined follow-up to hypothesis generation, in which explanations of how the formative measures are able to interact to form an organic whole. Even the *Ansatz* in mathematics must eventually be validated by the results it leads to. What proponents and opponents of formative measures might be able to agree to, is an informal convention by which formative measures must be validated when used. These informal conventions are not uncommon in science, e.g., as in the use of certain goodness-of-fit statistics for evaluating structural equation models, or in the use of 0.01 and 0.05 as p-values. This approach could lead to a new role for the Precautionary Principle: as a tool for identifying social fears, which fears could then be evaluated using traditional risk assessment techniques.

Risks, according to Beck (1992 [1986]: 19–20), are the unintended consequences of the rapid development of science and technology in late modern (capitalist) society (Rasborg 2012); and these risks may be responsible for late modern society's distinctive culture of fear (Furedi and Derbyshire 1997, Glassner 2010, Hanekamp et al. 2005, Tudor 2003). But our responses to risks, such as our deployment of the Precautionary Principle, also have unintended consequences. For one, the Precautionary Principle validates and operationalizes the fear of uncertainty. But the fear of uncertainty can be a non-propositional fear (Davis 1987) in disguise, i.e., anxiety about technology and its possible but unknowable effects on us. Yet an uncertain future stimulates innovation. The uncertain future is a nothingness that acts against the present to form a creative potential. The great varieties of religion and other forms of innovative metaphysical speculation, for example, would be unimaginable without the influences of the uncertain province of death. Embracing the uncertain future is what gives us freedom: the uncertain future is a blank canvas upon which we paint our lives, limited only by our imagination and our desire to remain free. Fear of uncertainty is fear of freedom. Flight from uncertainty is the flight from freedom. Fear of uncertainty stifles innovation. Fear of uncertainty leads us to rend the canvas upon which we would otherwise paint our desired future. Yet the fear of uncertainty also likely saved us, in evolutionary time, from predators, volcanoes and other natural hazards. The fear of uncertainty is the fear of freedom, but lack of fear of uncertainty is potentially suicidal, and that takes us back to the Precautionary Principle. The answer to this paradox, and to the question of the Precautionary Principle, is not to disregard fear; rather, once fear is identified, the answer is to face it head-on. Again, this suggests that the most valuable use of the Precautionary Principle may be to identify fears; fears that may then be subject to analytic assessment and action based on scientific judgment. What we are recommending is a dynamical process that iterates between fear and analysis. Previously either we felt fear or we ignored it. We are suggesting that we feel fear and then ignore it.

Along these lines, usage of the Precautionary Principle should be restricted to its first two dimensions, threat and uncertainty, ontology and epistemology. The flashpoints of the Precautionary Principle are its two final dimensions, Action and Command. Those two dimensions should remain within the province of traditional risk assessment. We should act not out of (fear of) uncertainty, but out of rationality and resolve. An example of the successful application of this method is Cerf and Condron's (2006) case study on how milk pasteurization heat treatment procedures were driven by the requirement to destroy *Coxiella burnetii* and thereby eradicate Q fever. It is still an open question whether Q fever is a foodborne disease or if pasteurization is scientifically justified for the prevention of Q fever. However, rather than either eliminating milk from our diets or ignoring these fears, precautionary procedures were implemented; and now that there exists more evidence, scholars such as Cerf and Condron are beginning to rationally question these precautionary procedures. The minimum actions were taken for what appeared to be self-preservation, but the scholarly community did not adopt epistemic closure with respect to the issue.

## CONCLUSION

In the preceding, we argued that the Precautionary Principle is an index of formative measures of risk and fear. We mapped Todt and Luján (2014) and Slovic's (1987) risk components onto the Precautionary Principle. This mapping showed that the Precautionary Principle is directed the layperson's view of risk, i.e., to both dread risk and unknown risk. This mapping also showed that the Precautionary Principle comprises both ontological (threat) and epistemological (uncertainty) components. This approach appears to have considerable explanatory power regarding both the Precautionary Principle and its criticisms. It may also provide a path forward for opposing parties to work together to investigate if not implement the Precautionary Principle at a global level. Given the apparent desire by a large portion of society for such a principle, this potential path is notable. We suggested that the origins of Precautionary Principle should be investigated specifically in relation to the particular legal instrument in question. We recommended that usage of the Precautionary Principle should be restricted to its first two dimensions, threat and uncertainty; and that its two final dimensions, Action and Command, should remain within the province of traditional risk assessment.

## REFERENCES

Arcari, Maurizio. "The draft articles on the law of international watercourses adopted by the International Law Commission: an overview and some remarks on selected issues." In *Natural Resources Forum*, vol. 21, no. 3, pp. 169-179. Blackwell Publishing Ltd, 1997.

Ashford, Nicholas A. "The legacy of the precautionary principle in US law: The rise of cost-benefit analysis and risk assessment as undermining factors in health, safety and environmental protection." In *Implementing the Precautionary Principle: Approaches from the Nordic Countries, the EU and the United States*, pp. 352-378. Earthscan, London (2007).

Aven, Terje. "On different types of uncertainties in the context of the precautionary principle." *Risk Analysis* 31, no. 10 (2011): 1515-1525.

Barnard, Robert C., and Donald L. Morgan. "The National Academy of Sciences offers a new framework for addressing global warming issues." *Regulatory Toxicology and Pharmacology* 31, no. 1 (2000): 112-116.

Bates, Bethany M. "Reconciliation After Winter: The Standard for Preliminary Injunctions in Federal Courts." *Columbia Law Review* (2011): 1522-1556.

Beck, Ulrich. *Risk society: Towards a new modernity*. Sage, 1992 [1986].

Bodansky, Daniel. "Law: scientific uncertainty and the precautionary principle." *Environment: Science and Policy for Sustainable Development* 33, no. 7 (1991): 4-44.

Bodansky, Daniel. "Customary (and not so customary) international environmental law." *Indiana Journal of Global Legal Studies* (1995): 105-119.

Boehmer-Christiansen, Sonja. "The precautionary principle in Germany–enabling government." *Interpreting the Precautionary Principle* 31 (1994): 38-39.

Boumans, Marcel. "Fisher's instrumental approach to index numbers." *History of Political Economy* 33, no. 5 (2001): 313-344.

Cameron, James, and Juli Abouchar. "The precautionary principle: a fundamental principle of law and policy for the protection of the global environment." *Boston College International and Comparative Law Review.* 14 (1991): 1.

Carter, J. Adam, and Martin Peterson. "On the epistemology of the precautionary principle." *Erkenntnis* 80, no. 1 (2015): 1-13.

Carter, J. Adam, and Martin Peterson. "On the Epistemology of the Precautionary Principle: Reply to Steglich-Petersen." *Erkenntnis* 81, no. 2 (2016): 297-304.

CBOE. (2016). *The VIX Index calculation*. Retrieved from http://www.cboe.com/micro/vix/part2.aspx.

Cerf, O., and R. Condron. "Coxiella burnetii and milk pasteurization: an early application of the precautionary principle?." *Epidemiology and Infection* 134, no. 05 (2006): 946-951.

Clarke, Steve. "Future technologies, dystopic futures and the precautionary principle." *Ethics and Information technology* 7, no. 3 (2005): 121-126.

Clements, Kenneth W., and Haji Yaakob Izan. "The measurement of inflation: a stochastic approach." *Journal of Business & Economic Statistics* 5, no. 3 (1987): 339-350.

Curtis, Richard F., and Elton F. Jackson. "Multiple indicators in survey research." *American Journal of Sociology* 68, no. 2 (1962): 195-204.

Dana, David. "The contextual rationality of the precautionary principle." *Queen's Law Review* 35 (2009): 67-95.

Davis, Wayne A. "The varieties of fear." *Philosophical Studies* 51, no. 3 (1987): 287-310.

Derbyshire, Stuart WG. "Culture of Fear: Risk Taking and the Morality of Low Expectation." *BMJ-British Medical Journal-International Edition* 315, no. 7111 (1997): 823.

Diamantopoulos, Adamantios, and Judy A. Siguaw. "Formative versus reflective indicators in organizational measure development: A comparison and empirical illustration." *British Journal of Management* 17, no. 4 (2006): 263-282.

ECJ. (2010). European Court of Justice: Judgment of the Court (Second Chamber) of 22 December 2010. Gowan Comércio Internacional e Serviços Lda v Ministero della Salute.

ECJ. (2011). European Court of Justice: Advocate General Yves Bot's Opinion in Case C-442/09. 9 February 2011.

Edwards, Jeffrey R. "The fallacy of formative measurement." *Organizational Research Methods* 14, no. 2 (2011): 370-388.

Esqueda, Omar A., Yongli Luo, and Dave O. Jackson. "The linkage between the US "fear index" and ADR premiums under non-frictionless stock markets." *Journal of Economics and Finance* 39, no. 3 (2015): 541-556.

Francot-Timmermans, Lyana, and Ubaldus De Vries. "Eyes Wide Shut: On Risk, Rule of Law and Precaution." *Ratio Juris* 26, no. 2 (2013): 282-301.

Frost, Tom. "The promise of liberty to all: the long march to marriage equality." *Liverpool Law Review* 36, no. 2 (2015): 171-182.

Giampietro, Mario. "The precautionary principle and ecological hazards of genetically modified organisms." *AMBIO: A Journal of the Human Environment* 31, no. 6 (2002): 466-470.

Giroux, Élodie. "Epidemiology and the bio-statistical theory of disease: a challenging perspective." *Theoretical Medicine and Bioethics* 36, no. 3 (2015): 175-195.

Glassner, Barry. *The culture of fear: Why Americans are afraid of the wrong things: Crime, drugs, minorities, teen moms, killer kids, mutant microbes, plane crashes, road rage, & so much more*. Basic Books, 2010.

Hanekamp, Jaap C., Guillaume Vera-Navas, and S. W. Verstegen. "The historical roots of precautionary thinking: the cultural ecological critique and 'The Limits to Growth'." *Journal of Risk Research* 8, no. 4 (2005): 295-310.

Hansen, Bent, and Edward F. Lucas. "On the accuracy of index numbers." *Review of Income and Wealth* 30, no. 1 (1984): 25-38.

Heselhaus, Sebastian. "Nanomaterials and the Precautionary Principle in the EU." *Journal of Consumer Policy* 33, no. 1 (2010): 91-108.

Hilbert, David. *Grundlagen der Geometrie: Festschrift zur Feier der Enthüllung des Gauss-Weber-Denkmals in Göttingen. Herausgegeben von dem Fest-Comitee. I. Theil*. Teubner, 1899.

Hilbert, David. *The foundations of geometry*. Open Court Publishing Company, 1902.

Hilbert, David. "Axiomatisches Denken." *Mathematische Annalen* 78, no. 1 (1917): 405-415.

Howell, Roy D., Einar Breivik, and James B. Wilcox. "Reconsidering formative measurement." *Psychological Methods* 12, no. 2 (2007): 205.

Keyes, Katherine, and Sandro Galea. "What matters most: quantifying an epidemiology of consequence." *Annals of Epidemiology* 25, no. 5 (2015): 305-311.

Krause, Décio, Jonas RB Arenhart, and Fernando TF Moraes. "Axiomatization and models of scientific theories." *Foundations of Science* 16, no. 4 (2011): 363-382.

Leubsdorf, John. "The standard for preliminary injunctions." *Harvard Law Review* (1978): 525-566.

Mandel, Gregory N., and James Thuo Gathii. "Cost-Benefit Analysis Versus the Precautionary Principle: Beyond Class Sunstein's Laws of Fear." *University of Illinois Law Review* 5 (2006): 1037-1079.

Marchant, Gary E. "The precautionary principle: an 'unprincipled' approach to biotechnology regulation." *Journal of Risk Research* 4, no. 2 (2001): 143-157.

McCaffrey, Stephen C. "The International Law Commission adopts draft articles on transboundary aquifers." *The American Journal of International Law* 103, no. 2 (2009): 272-293.

McIntyre, Owen, and Thomas Mosedale. "The precautionary principle as a norm of customary international law." 9 *Journal of Environmental Law* (1997): 221-240.

Pasch, Moritz. *Vorlesungen über die neuere Geometrie: Mit einem Anhang von Max Dehn: Die Grundlegung der Geometrie in historischer Entwicklung.* Vol. 23. Springer-Verlag, 2013 [1882].

Peckhaus, Volker. "The pragmatism of Hilbert's programme." *Synthese* 137, no. 1-2 (2003): 141-156.

Peterson, Martin. "The precautionary principle is incoherent." *Risk Analysis* 26, no. 3 (2006): 595-601.

Raffensperger, C. and Tickner, J. "Introduction: to foresee and forestall." In C. Raffensperger and J. Tickner (Eds.), *Protecting Public Health and the Environment: Implementing the Precautionary Principle*, pp. 1–11. Washington, DC: Island Press, 1999.

Rasborg, Klaus. "'(World) risk society'or 'new rationalities of risk'? A critical discussion of Ulrich Beck's theory of reflexive modernity." *Thesis Eleven* 108, no. 1 (2012): 3-25.

Rogers, Michael D. "Risk management and the record of the precautionary principle in EU case law." *Journal of Risk Research* 14, no. 4 (2011): 467-484.

Sadeleer, Nicolas de. "The precautionary principle in EC health and environmental law." *European Law Journal* 12, no. 2 (2006): 139-172.

Sandin, Per. "Dimensions of the precautionary principle." *Human and Ecological Risk Assessment: An International Journal* 5, no. 5 (1999): 889-907.

Savitz, David A. "In defense of black box epidemiology." *Epidemiology* (1994): 550-552.

Siegrist, Michael, Carmen Keller, and Henk AL Kiers. "A new look at the psychometric paradigm of perception of hazards." *Risk Analysis* 25, no. 1 (2005): 211-222.

Skrabanek, Petr. "The emptiness of the black box." *Epidemiology* 5, no. 5 (1994): 553-554.

Slovic, Paul. "Perception of risk." *Science* 236, no. 4799 (1987): 280-285.

Stebbing, Margaret. "Avoiding the trust deficit: public engagement, values, the precautionary principle and the future of nanotechnology." *Journal of Bioethical Inquiry* 6, no. 1 (2009): 37-48.

Steglich-Petersen, Asbjørn. "The epistemology of the precautionary principle: Two puzzles resolved." *Erkenntnis* 80, no. 5 (2015): 1013-1021.

Stewart, Richard B. "Environmental regulatory decision making under uncertainty." In Timothy Swanson (ed), *An Introduction to the Law and Economics of Environmental Policy: Issues in Institutional Design*, pp. 71-126. Emerald Group Publishing Limited, 2002.

Stöltzner, Michael. "Hilbert's axiomatic method and Carnap's general axiomatics." *Studies in History and Philosophy of Science Part A* 53 (2015): 12-22.

Sunstein, Cass R. "The paralyzing principle." *Regulation* 25 (2002): 32-37.

Todt, Oliver, and José Luis Luján. "Analyzing precautionary regulation: do precaution, science, and innovation go together?." *Risk Analysis* 34, no. 12 (2014): 2163-2173.

Tudor, Andrew. "A (macro) sociology of fear?." *The Sociological Review* 51, no. 2 (2003): 238-256.

Verschuuren, Jonathan. "Sustainable development and the nature of environmental legal principles." *Potchefstroom Electronic Law Journal/Potchefstroomse Elektroniese Regsblad* 9, no. 1 (2006).

Wagner, Wendy E. "The precautionary principle and chemical regulation in the US." *Human and Ecological Risk Assessment* 6, no. 3 (2000): 459-477.

Wahlström B. "The precautionary approach to chemicals management: A Swedish perspective." In C. Raffensperger and J. Tickner (Eds.). *Protecting public health and the environment: implementing the precautionary principle* (51-70). Washington, DC: Island Press, 1999.

Zimmermann, Rainer E. "Topological aspects of biosemiotics." *tripleC: Communication, Capitalism & Critique. Open Access Journal for a Global Sustainable Information Society* 5, no. 2 (2007): 49-63.