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Is the Precautionary Principle Really Incoherent?

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The Precautionary Principle has been an increasingly important principle in international treaties since the 1980s. Through varying formulations, it states that when an activity can lead to a catastrophe for human health or the environment, measures should be taken to prevent it even if the cause-and-effect relationship is not fully established scientifically. The Precautionary Principle has been critically discussed from many sides. This article concentrates on a theoretical argument by Peterson (2006) according to which the Precautionary Principle is incoherent with other desiderata of rational decision making, and thus cannot be used as a decision rule that selects an action among several ones. I claim here that Peterson's argument fails to establish the incoherence of the Precautionary Principle, by attacking three of its premises. I argue (i) that Peterson's treatment of uncertainties lacks generality, (ii) that his Archimedian condition is problematic for incommensurability reasons, and (iii) that his explication of the Precautionary Principle is not adequate. This leads me to conjecture that the Precautionary Principle can be envisaged as a coherent decision rule, again.

KEY WORDS: Decision rule; incoherence; precautionary principle; risk; uncertainty

1. INTRODUCTION

The Precautionary Principle (hereafter, PP) has been an increasingly important principle in international treaties about health and the environment since the 1980s. It has been invoked on major topics such as climate change, biodiversity, nuclear energy, drugs, or various technological advances. Several formulations of PP have been advanced over time, and no one has gained universal agreement. One of the earliest major formulation can be found in the 1992 UN Rio Declaration:

> "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."(1)

Another standard formulation is given by the Wingspread Statement:

> "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically."(2)

One of the formulations considered in a recent philosophical analysis of PP is (p. 28):

> "If a scientifically plausible mechanism exists whereby an activity can lead to a catastrophe, then that activity should be phased out or significantly restricted."(3)

It is generally considered that PP does not apply when precise quantitative predictions can be made, but when probabilities cannot be assigned to events or when no accurate predictive model can be established.(3–5)

If the PP has no unique formulation, it has no unique scope or role either. According to Ref. (6, pp. 971–972), PP can be viewed as:

- a decision rule or a rule of choice: it is used to select one specific action or policy among several ones;

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- a meta-principle or a procedural requirement: it places general conditions on how actions or policies should be chosen;
- an epistemic principle: it tells how inferences should be made and what should be believed—as opposed to what should be done.

PP is controversial, both in society and among scholars. According to some authors,

> "the precautionary principle may well be the most innovative, pervasive, and significant new concept in environmental policy over the past quarter century. It may also be the most reckless, arbitrary, and ill-advised." (p. 1 in Ref. 8, cited in Ref. 3, p. 1)

Criticism on PP comes from many sides: some argue that weak versions of PP tend to be trivial—no one would claim that certainty is required for taking precaution—–, and that strong ones are incoherent—precautionary regulations can lead to harmful effects and thus would be precluded by PP itself.[1] One of the most-cited arguments against PP can be found in Ref. (9), in a paper entitled "The Precautionary Principle is Incoherent" (and continued in Refs. (10,11)). It has been influential in arguing that PP cannot be coherently considered as a decision rule, that is, to select one specific action among several ones, because it conflicts with other (well-established) decision theoretic desiderata. The role of PP, Peterson argues, can be only to guide our beliefs, or to serve as a meta-principle. Peterson's argument fits in the more general debate on the incoherence of PP.[(12–18)]

Is there no way PP can be used to guide our actions or choices? My aim is to investigate the soundness of Peterson's incoherence argument, so as to understand what is really wrong and incoherent in viewing PP as a decision rule. I shall argue that the incoherence argument fails, because some of its premises should be rejected. This leads me to suggest that PP can be viewed again as a decision rule. To prevent misunderstandings, note that I do *not* provide some positive justifications for PP, neither defend some specific version of it here (not more than the standard versions recalled above).

The outline of the article is as follows. I first present Peterson's incoherence theorem in Section 2. I then turn to the criticism of its premises: the way uncertainties are treated in Section 3, Peterson's Archimedean condition in Section 4, and his explication of PP in Section 5. Section 6 concludes.

[1]For reviews of criticisms, see Ref. (3, chap. 1) and Refs. (6,7).

2. PETERSON'S INCOHERENCE THEOREM

Peterson [(9)] focuses on PP as a decision rule. He establishes two incoherence theorems (with variants in the premises): PP, conjoined with several decision theory desiderata, leads to a contradiction.

The framework he considers is the following. The decisionmaker can choose between several *actions*, noted X, Y, ... For instance,

- $X =$ use a pesticide,
- $Y =$ do not use it.

Each action is associated with several possible *outcomes*, depending on the state of the world that actually obtains. The decisionmaker is in a case of uncertainty: she does not know which state of the world will obtain, and her knowledge amounts to qualitative information, like "extremely likely" or "not very likely"—she cannot attribute probabilities to the various states of the world.

Outcomes are denoted $a, b, \ldots z$ according to their *desirability*. They can be either *nonfatal* (a, b, ...) or *fatal* (p, q, ...). For instance, the outcomes may be

- $a =$ crops improved;
- $b =$ crops not improved;
- $p =$ crops improved + 1,000 deaths/year in the Netherlands.

The rationale behind the fatal/nonfatal distinction is that PP does not apply to any outcome, but only to the ones judged as really harmful or fatal, that is, the p, q, ... The existence of such a fatality limit that triggers the application of PP is uncontroversial in the literature.[2] As Peterson notes, p. 597,[3]

> "No precise level [of fatality] has to be decided upon. Furthermore, we need not assume that the boundary between fatal and nonfatal outcomes is sharp. There might be an area of vagueness, in which outcomes are neither fatal nor nonfatal."

Peterson also acknowledges that "From a formal point of view, the term 'fatal' has no meaning, it just denotes a cut-off point" (p. 597).

Peterson's proof relies on a formal explication of PP. Or rather, since no unique formulation of PP is recognized in the literature, several explications of

[2]"Fatality" corresponds to the "harm" or "threat" condition of some authors.[(3,19)]

[3]In the rest of this article, all page references are to Peterson's paper,[(9)] unless otherwise noted.

PP are considered in turn—PPα, PPβ, PPγ, and PPδ. They

> "are intended as minimal criteria that advocates of different versions of the precautionary principle ought to agree upon, no matter which version of the principle happens to be their personal favorite." (pp. 598–599)

In other words, Peterson has it that any sensible interpretation of PP should imply his (rather weak) versions PPα, PPβ, PPγ, and PPδ.

Peterson proves two incoherence theorems: his first one applies to PPα, and his second one to PPβ, PPγ, and PPδ. My discussion will be centered on the second theorem, because it is the most refined and powerful one.[4] Among PPβ, PPγ, and PPδ, the latter is the more general, as it is logically implied by each of the first two. As a consequence, I shall focus on PPδ only. Its expression is:

> PPδ: If one act is more likely to give rise to a fatal outcome than another, then the latter should be preferred to the former, given that: (i) both fatal outcomes are equally undesirable and (ii) not negligibly unlikely and (iii) the nonpreferred act is sufficiently more likely to lead to a fatal outcome than the preferred one. (p. 599)

The formulation of PPδ calls for several remarks. Condition (ii) expresses the *de minimis* principle: there is a probability (or likelihood) threshold under which risks are so unlikely to arise that they should be neglected in the analysis.[20,21] Though not uncontroversial in general, this principle is used by regulatory agencies and it is rather well accepted in precautionary contexts—otherwise, precaution might apply to any far-fetched possible outcome and would be paralyzing. Peterson's expression "sufficiently more likely" used in PPδ is not defined, but my criticism will not bear on that point. The most important point to note in PPδ is that *only the most likely fatal outcome* of each act matters and is compared (this is clearer in Peterson's formal expression of PPδ in his appendix). Other less likely fatal outcomes, if there are some, are not taken into account. Note finally that PPδ is not supposed to capture *the* true meaning of PP (on which there is currently no consensus as recalled in Section 1), or even to be a complete explication of (one version of) PP. Peterson only claims that PPδ is a *consequence* of any version of PP, and that "Presumably, PPδ is so weak that it cannot reasonably be refuted by any advocate of the precautionary principle" (p. 599).

Table I. An Illustration of the Archimedean Condition with Probabilities (Adapted from Ref. (3, p. 41))

Gain	+10	+5	−5	−10
Original probability	0.25	0.25	0.25	0.25
Modified probability	0.15	0.35	0.35	0.15

Note: After an increase of the probability of the +5 gain from 0.25 to 0.35 (relatively to the probability of the +10 gain which decreases from 0.25 to 0.15), a balance is reached by decreasing the probability of the −10 gain from 0.25 to 0.15 (relatively to the probability of the −5 gain, which increases from 0.25 to 0.35).

Another premise of the incoherence theorem is the Archimedean condition, which is introduced in Peterson's article[9] for the first time:

> Archimedes: "If the relative likelihood of a nonfatal outcome is increased in relation to a strictly better nonfatal outcome, then there is some (nonnegligible) decrease of the relative likelihood of a fatal outcome that counterbalances this precisely." (p. 599)

This condition reflects a particular way in which "to some extent, both the likelihood and the desirability of an outcome matter" (p. 599). It says that a change of likelihood of a nonfatal outcome can be compensated by a change of likelihood of fatal outcome. Even if this condition applies to a qualitative framework, it is perhaps easier to understand it through an example with probabilities, as in Table I.

Finally, two standard decision theory conditions are considered:

> "Dominance: If one act yields at least as good outcomes as another under all possible states of the world, then the latter is not preferred to the former.
>
> Total Order: Preferences between acts are complete, asymmetric, and transitive." (p. 597)

Then, Peterson's[9] second incoherence theorem is: PPδ, Archimedes, Total Order, and Dominance are together logically inconsistent, that is, they imply a logical contradiction.[5] Given that the last three conditions seem reasonable ones, Peterson concludes that the faulty ingredient is PPδ, and hence that PP more generally cannot be used as a decision rule. Note the particularity of Peterson's incoherence argument: it is not that the *formulation* of PP contradicts itself, neither is it that PP, when applied

[4] The reader interested in Peterson's first theorem can easily adapt my argument against PPδ in Section 5 to apply it to PPα.

[5] Peterson's proof is formal, based on formal expressions of all his premises. As the presentation and the discussion of these formal developments would add nothing to my points, I stay at the level of the informal expressions.

about different risks, implies *decisions* which contradict themselves. It is that PP contradicts *with other desiderata* of good decision making. So, one might better say that what Peterson argues for is not that PP is *incoherent*, but that it is *inconsistent* with other conditions. For simplicity, however, I will continue to use his terminology.

I shall not attack the logical validity of the argument, but its premises. In Section 3, I argue that because of the way uncertainties are treated, the theorem implicitly restricts the application of PP to a fraction of the cases discussed in the literature. Then in Section 4, I argue that the Archimedean condition is not a sensible requirement in the context of precaution. Finally in Section 5, I argue that PPδ does not correspond to the intuition of PP. These three points are independent. The first one restricts the generality of the incoherence theorem, and each of the last two is sufficient to make the theorem collapse.

3. AGAINST PETERSON'S TREATMENT OF UNCERTAINTIES

In this section, I claim that the framework assumed for Peterson's incoherence theorem is not general enough to apply to all cases to which PP is supposed to apply according to the literature. So, even if the theorem's conclusion held (but this is denied in Sections 4 and 5), and even if PP was indeed incoherent as Peterson claims, it would only be proven with a small scope and would actually not apply to the most interesting cases. For that, I argue that PPδ, the Archimedean condition and the Dominance condition (i.e., three in four premises of the theorem) rely on some implicit assumptions about uncertainties that are not shared in the literature.

Note that these three premises compare outcomes of acts (the desirabilities of the outcomes for the Dominance condition, their likelihoods for the Archimedean condition, and both their desirabilities and their likelihoods for PPδ). Even if this comparison is made qualitatively rather than quantitatively (pp. 596–597), it requires that one comes up with a set of all possible outcomes for the decisions under consideration. In the example from Section 2, one must be able to associate acts X and Y with some possible outcomes a, b, and p. In other words, three premises of Peterson's theorem require the decisionmaker to know the state space of the decision problem.

However, this is not the mainstream view in the literature, which considers that PP applies both when the state space is known and when it is not. I shall illustrate this with two papers. First, Stirling and Gee[5] distinguish (pp. 524–526) between two dimensions in the knowledge of a situation: the knowledge about outcomes and the knowledge about likelihoods. Outcomes can be either well or poorly defined, and there can be some or no basis for likelihoods (or probabilities). The case where outcomes are well defined and there is some basis to assign probabilities to them corresponds to the formal definition of *risk* analogous to Ref. 22. The other extreme is called "ignorance": there is no basis for assigning probabilities, and "the definition of a complete set of outcomes is also problematic" (Ref. (5, p. 525))—that is, the state space is not fully known, *contra* Peterson. This latter feature amounts to "an acknowledgement of the possibility of surprise. [...] It is always possible that there are effects (outcomes) that have been entirely excluded from consideration" (ibid). According to Stirling and Gee, it is in this case that PP has a decisive role to play. They give examples:

> "Past examples of the importance of this condition [of ignorance and of surprise] are evident in high-profile cases such as stratospheric-ozone depletion by chlorofluorocarbons, the links between bovine spongiform encephalopathy in cows and variant Creutzfeldt-Jakob disease in humans, and the emergence of recognition of the endocrine-disruption mechanism in chemicals regulation." (ibid.)

So, Stirling and Gee's position is that a most important case in which PP applies is when outcomes are poorly defined. This cannot be handled by three premises in Peterson's theorem.

Aven[4] discusses Stirling and Gee's contribution and offers a different classification system. He argues that the uncertainties that trigger the application of PP (which he calls "scientific uncertainties") consist in the absence of an accurate prediction model. This is the case for instance when scientists do not agree on what the effects of an oil spill on fish species would be. If scientists have difficulties in specifying the set of possible consequences of some acts, that is, in specifying the state space, *a fortiori* they are not in a position to accurately predict these consequences. In this case, in Aven's view, the uncertainties can be qualified as "scientific" and the PP should apply. But again, three of the premises in Peterson's theorem are not satisfied in this case, as they require a specified state space. Overall, the positions defended by Stirling and Gee[5] and by Aven[4] imply that Peterson's theorem cannot apply to every situation concerned by PP. So, supposing that the theorem holds, it can only be concluded that PP is incoherent on one part of the situations, namely those where the state space is known, and not on the most interesting ones, when the state space is unknown.

Aven[(4)] goes even further (pp. 1520–1522). He claims that a mere lack of knowledge on probabilities of outcomes, be they interpreted in a frequentist or in a subjectivist way, does not count as a "scientific uncertainty," and hence is not sufficient for PP to apply. Peterson's framework falls into this category: the qualitative likelihoods that are assigned to outcomes can be considered as likelihoods with large uncertainties (for instance, one can imagine some correspondence between a qualitative scale and quantitative intervals). Hence, it seems that Aven[(4)] would deny that Peterson's theorem is actually considering proper cases of application of PP. On Aven's view, Peterson's result amounts to showing that PP is incoherent when it does not apply, which counts as no valuable news.

Independently from the criticism about uncertainties discussed in this section, I argue in the next sections against two specific premises of Peterson's theorem—the Archimedean condition and PPδ.

4. AGAINST THE ARCHIMEDEAN CONDITION

Recall that the Archimedean condition requires that a change of likelihood of a *nonfatal* outcome can be compensated by a change of likelihood of a *fatal* outcome. Peterson motivates it with the idea that "to some extent, both the likelihood and the desirability of an outcome matter" (p. 599). The Archimedean condition also seems to express a reminiscence of the classical framework of expected utility, in which all benefits and drawbacks can be compensated one against another, given suitable likelihoods (the expected utility framework cannot apply directly, because no quantitative information is available). On the contrary to Total Order and Dominance, the Archimedean condition does not belong to standard decision theory, nor has been advocated by the proponents of PP. It is introduced for the first time by Peterson in his[(9)] just for this incoherence theorem, and it is of course a crucial ingredient in the proof. Hence, this Archimedean condition calls for particular scrutiny.

I have two criticisms against the Archimedean condition, in relation with incommensurability issues.[6] My first criticism is related to the fatal/nonfatal outcome distinction. As Peterson rightly insists, such a distinction is crucial to the spirit of PP. Some outcomes are catastrophic or fatal, while some are not, and the concern of PP is to avoid the former. In other words, the very idea of a fatal outcome is that it is of a different kind of, that of nonfatal ones. Typically, fatal outcomes are irreversible ones: human deaths, extinction of living species, nuclear accidents, global warming . . .[7] Why should fatal outcomes deserve a particular treatment? As Peterson puts it,

> "The intuition underlying PP is that some outcomes are *so bad* that they ought to be avoided (if possible) *even if the potential benefit of accepting such a risk is enormous*." (p. 597, my emphasis)

This means that the low desirability of the fatal outcomes cannot be compensated by large benefits from some nonfatal outcomes. This implies a value incommensurability between fatal and nonfatal outcomes. Although one may not agree with it,

[6] Steel[(3)] offers the only criticism I am aware of this Archimedean condition (pp. 41–42). His argument is that the Archimedean condition is not sensible when reasoning in a qualitative framework (i.e., with qualitative likelihoods and fatalities, or utilities): which amounts of changes in relative likelihoods will *precisely* compensate? Steel argues that in a qualitative framework, precise compensation is not well defined or may be impossible, and that the Archimedean condition requires a quantitative framework. This objection is interesting, but Peterson might have the following reply. In the proof of the incoherence theorem, the framework of application of the Archimedean condition (be it qualitative or quantitative) is only used to posit the theoretical existence of some outcomes with specific properties, and it is not required that agents who apply PP know them or use the framework. So, the reply might go, when an agent uses a qualitative framework in which the precise compensation is not possible, one can consider an additional finer-grained framework, in which the compensation makes sense. For instance, if likelihoods are interpreted epistemically, it is easy to define more precise ones obtained by a better informed agent, or similarly to define the more precise fatality estimates an agent might reach through introspection. So, the reply might conclude, the Archimedean condition still holds if it is assumed that the individual estimates of likelihoods and fatalities could theoretically be improved. So, Steel's objection needs to assume that there is no sense in theoretically defining finer grained (quantitative) likelihoods or fatalities for an individual—note that the question is not whether there exist such *objective* quantities. Although this assumption may hold in some cases, it will fail for many interesting ones. My own objections against the Archimedean condition are intended to apply with more generality.

[7] "Irreversible" can be taken to mean that there is no way to reach the original state, or no way to reach it within a finite time scale that is meaningful for human life—the original state might be accessible in the last two examples, but in thousands of years, which is not of real value for humanity.

it is at the root of Peterson's view of PP. Hence, if one accepts PP (in Peterson's sense), one is committed to this view of incommensurability between fatal and nonfatal outcomes. Now, the problem is that the Archimedean condition is saying exactly the opposite: by stating that a change in the likelihood of nonfatal outcomes can be compensated by a change in the likelihood of fatal outcomes, it assumes that the desirability of fatal and nonfatal outcomes can be compared—even if one change of likelihood has to be much smaller than the other—and thus that fatal and nonfatal outcomes are commensurable. In this sense, the Archimedean condition plainly rejects the "intuition underlying PP."[8]

The upshot is thus the following: if one accepts PP, then one cannot accept the Archimedean condition, and the incoherence theorem cannot proceed.[9] So, if one accepts PP, it cannot be proven (with Peterson's theorem) that PP is incoherent. One may or may not agree with PP, but at least holding it does not imply inconsistency. Note that the problem is really of a direct conflict between PP and the Archimedean condition. Peterson's incoherence theorem may suggest that PP is incompatible with several decision theoretic desiderata taken together, in some holistic fashion, but the story is much simpler: you cannot accept both PP and the Archimedean condition, because they rely on opposite views. So it is no surprise that a contradiction can be derived from the two.

My second criticism against the Archimedean condition is that it assumes a value commensurability between outcomes in general. Outcomes may affect different areas, like the environment, human health, the economics, or different people in various regions of the world. Value commensurability between the desirability of outcomes is a central assumption of standard cost–benefit analysis—the dollar serving as the common value scale. But risk analysis usually refrains from doing so, and insists on keeping the risks or the benefits in their natural units, like the number of deaths. As Steel[(3)] summarizes on p. 114,

> Value commensurability has been the target of a good deal of criticism.[(23–25)] Critics charge that monetary valuations of impacts on human health or the environment are arbitrary and that they obscure considerations pertaining to rights and justice that would normally be considered essential.[(24)]

My worry is on a normative ground:[10] if it is not fair to balance an economic gain somewhere with a loss of human lives elsewhere, then our framework should not assume in general a value commensurability between outcomes. Yet, the Archimedean condition assumes that all outcomes can be compared, so that changes in the likelihood of some outcomes can be compensated by changes in the likelihood of some other outcomes. This gives another reason to reject the Archimedean condition.

5. AGAINST PETERSON'S EXPLICATION OF THE PP

Let us now turn to another premise of the theorem: PPδ. It is claimed to be an explication of PP, or at least a consequence of the various versions of PP. Even if Peterson does not claim that PPδ captures *the* true and complete meaning of PP, at least he writes that it "cannot reasonably be refuted by any advocate of the precautionary principle" (p. 599). I argue in this section that this is not so: PPδ is not a suitable explication of PP even in this sense.[11]

The source of the problem I identify lies in the fact that PPδ considers only the most likely fatal outcome for each action and disregards other fatal outcomes. On the contrary, the literature on PP generally insists on considering the whole spectrum of outcomes, especially when several fatal outcomes may occur.[12] For instance, when assessing the risk posed by a vaccine, medical experts are interested in the heart failures it may cause, but also in the kidney failures—even if the kidney failures are less likely than the heart ones. That PPδ is biased is not without consequences: it can recommend an action which is at odds with the action recommended by any intuitive reading of PP.

[8]As indicated above, the Archimedean condition seems to express a reminiscence of the classical framework of expected utility, in which all benefits and drawbacks can be compensated one against another, given suitable likelihoods. This is exactly what PP rejects with the fatal/nonfatal distinction.

[9]Note that if one does not accept PP, then one can accept the Archimedean condition, and the incoherence theorem cannot proceed either.

[10]For a critical discussion of the descriptive dimension of the value commensurability thesis, cf. Ref. (3, pp. 113–118).

[11]This argument comes in addition to, and independently from, the one developed in Section 3, according to which PPδ only deals with one part of the situations of interest for PP, namely those in which the outcomes of actions are known.

[12]There are exceptions. Some have argued for a similarity between PP and the maximin rule, which recommends to choose the least bad worst case outcome.[(23,24,26,27)] Others have focused on the minimax regret rule.[(28)] But maximin or minimax do not seem to be right formalizations of PP, cf. Ref. (3, pp. 49–62).

Table II. Outcomes According to the State of the World that Obtains, and to the Action Performed

State	S_1	S_2	S_3	S_4	...	S_n
Action X	a	a	p	p	...	p
Action Y	a	p	a	a	...	a

Note: a = leak repaired. p = the repair team dies.

To make things concrete, let us consider an example on which our precautionary intuitions can be tested. A nuclear power plant is leaking, and the characteristics of the leak is not precisely known. The security service envisages two actions X and Y that the repair team might perform. n (larger than four) states of the worlds might obtain, with the following properties: each state S_i is more likely than S_{i+1}, S_3 is sufficiently less likely (in Peterson's sense in PPδ) than S_2, all $S_3, \ldots, S_n$ are almost as likely, and none of these states are negligibly unlikely. Two outcomes can occur: a, in which the leak is repaired, and p, in which the repair team dies. The former outcome is considered as nonfatal, and the latter as fatal (for instance, the repair team is composed of 10 persons, but it might be any number to suit one's fatality limit). Table II indicates the outcomes according to the action and to the state of the world, to the best of the security service's knowledge.

Which action should be chosen, according to an intuitive understanding of PP (i.e., following the statements from the introduction)? Any action X or Y may lead to the fatal outcome p or to the nonfatal outcome a, so what matters is the comparative likelihood of these outcomes. With action Y, a fatal outcome occurs in only one state of the world (S_2), while with action X it occurs for several states of the world ($S_3, \ldots, S_n$). S_2 is by hypothesis "sufficiently more likely" (in Peterson's sense in PPδ) than S_3. Even if what is meant by "sufficiently" is not defined by Peterson, if n is large enough (and it may be so for 5 or 10), then the cumulative likelihood of the states $S_3, \ldots, S_n$ will be larger than the likelihood of S_2.[13]

Table III. Table II with a State S' Defined by Merging States $S_3, \ldots, S_n$. S' Is More Likely Than S_2

State	S_1	S'	S_2
Action X	a	p	a
Action Y	a	a	p

To put things more clearly, let us define the state of the world S' that merges the states $S_3, \ldots, S_n$. Given that n is large enough, the likelihood of S' is larger than the likelihood of S_2, and the case analysis can thus be rewritten as in Table III. And it is quite clear then that action Y is more preferable than action X, because the only difference is that the same fatal outcome is less likely with Y than with X. This is so according to virtually any understanding of PP (and even according to standard expected utility theory).

Consider now the original case and Table II again: which action should be chosen according to PPδ? As indicated above, PPδ only compares the most likely fatal outcomes for each action, so here only the outcomes in S_3 for X and in S_2 for Y. Here is the definition of PPδ, with what corresponds to our example into brackets:

> "If one act [here, Y] is more likely to give rise to a fatal outcome [in S_2] than another [X, in S_3], then the latter [X] should be preferred to the former [Y], given that: (i) both fatal outcomes are equally undesirable [p in each case] and (ii) not negligibly unlikely [by hypothesis] and (iii) the nonpreferred act [Y] is sufficiently more likely to lead to a fatal outcome than the preferred one [by hypothesis, S_2 is sufficiently more likely than S_3]." (p. 599)

Thus, it is clear that X is preferable to Y. So, the intuitive understanding of PP and Peterson's explication of it with PPδ advise different actions in this example.

One might object that they do agree when the reformulation with the merged state S' is considered, like in Table III. Indeed, with this formulation, the most likely fatal outcomes for each action are now in opposite likelihood relations, and PPδ states that Y is preferable to X. So, the objection might go, the difference between the intuitive understanding of PP and PPδ has been artificially constructed because of the bizarre formulation with several almost identical states of the world ($S_3, \ldots, S_n$). My reply is twofold. First, the difference between the states

[13] One could object that likelihoods cannot be added because they are qualitative. But "qualitative" is compatible with a distance measure, as Peterson himself assumes with his "*sufficiently* more likely" (p. 599, my emphasis). Moreover, the qualitative framework can be best understood as drawn from a quantitative framework (for instance, "very unlikely" corresponds to a probability between 0% and 10%, like in the IPCC case, cf. Ref. (29, p. 142)), in which cumulative likelihoods make a clear sense; cf. also my footnote.[6] Note that I am comparing likelihoods of *fatal* outcomes only, and not likelihoods of *fatal* outcomes with *nonfatal* ones—I am not using something like the Archimedean condition that I have criticized in Section 4.

$S_3, \ldots, S_n$ can be more than artificial or abstract. For instance, each of them may correspond to the explosion of a specific device in the nuclear plant (like the previous heart/kidney example), or the example could be modified with outcomes of various desirability p for S_3, q for S_4, r for S_5, and so on. Second, even if PPδ selects the right action with one formulation of the problem (Table III), it remains that it *does not* with another formulation (Table II). The application of PPδ should *not* depend on the formulation of the case.[14] Or, if one wanted to claim that only some formulations of the case should be considered when applying PPδ, then one should specify (i) which ones, and most importantly (ii) why. For (i), I guess other counterexamples could be concocted against any general specification. For (ii), this would go against all the literature on PP, which has never considered that equivalent reformulations of cases could matter in anyway. To put it another way, PPδ's focus on the *most likely* fatal outcome for each act is vulnerable to a re-description of the case, which leads to an opposite conclusion.

Overall, I have presented a counterexample in which action Y is intuitively judged to be preferable to action X, but according to PPδ X is preferable to Y. So, PPδ cannot be considered to be an adequate explication of PP[15], and it can easily be refuted by advocates of PP. Peterson's incoherence theorem does not get off the ground because it considers a kind of straw man. PP itself is out of reach.

Why does PPδ fail to select the right action in this counterexample? The problem stems from the fact that PPδ evaluates the possible actions by considering for each action only the most likely fatal outcome, and by disregarding all other fatal outcomes. Yet, nothing in the standard formulations of PP (for instance, the ones recalled in Section 1) goes in such a direction. PP does not prevent several fatal outcomes from being taken into account. For instance, one may consider another counterexample in which action X involves a less likely but much more fatal outcome. To deal successfully with these counterexamples, it seems that an explication of PP should be a function of *several* fatal outcomes for each act, instead of just one, and should take into account both their likelihood and their desirability. My conjecture is that such a rule will not be incoherent anymore with other decision theoretic rules.[16]

One might object to my argumentative strategy that explications are hard to devise in general, and that any explication of a principle or of a rule might face some far-fetched counterexamples without admittedly being all wrong. In particular, one might object that PPδ selects the right action in most important cases, which is all that matters. But this would miss the following point: the proof of the incoherence theorem exactly relies on the fact that PPδ is concerned with one fatal outcome only for each action. In this sense, my counterexample is not pointing at some unimportant or secondary feature of PPδ, but at the heart of what makes the theorem work.

6. CONCLUSION

In this article, I have examined the question whether the PP is an incoherent decision rule. I have not shown that PP is coherent, but that the incoherence argument advanced by Peterson(9) does not hold. I have first attacked its general framework for dealing with uncertainties. Then, I have attacked two of the premises of the theorem: the newly introduced Archimedean condition, which is not a sensible requirement when one accepts PP, and Peterson's explication PPδ of PP. My three arguments are independent. The first one restricts the scope of the theorem, while each of the last two is sufficient to make the inconsistency theorem collapse. My conjecture is thus that PP can be considered again as a coherent decision rule. This should revive the interest for discussions on the right formulation of PP as a decision rule (cf. for instance, Ref. (3, pp. 27–28)).

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[14] It does not depend on the formulation with the intuitive reading of PP: the reformulation with Table III has only been considered to make the point clearer from a pedagogical viewpoint, and the preferable decision is the same in Table II.

[15] Similar counterexamples could be devised for the weaker versions PPα, PP β, PPγ.

[16] Note that the counterexample I have presented considers fatal outcomes of the *same* fatality level, so my argument does not rely on trade-offs to be made between better and worse fatal outcomes.

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