

Time for Caution

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Abstract

Precautionary principles are frequently appealed to both in public policy and in discussions of good individual decision-making. They prescribe omission or reduction of an activity, or taking precautionary measures whenever potential harmful effects of the activity surpass some threshold of likelihood and severity. One crucial appeal of precautionary principles has been that they seem to help guard against procrastinating on confronting and mitigating certain kinds of risk, namely those that are especially hard to quantify. Here I raise a challenge for precautionary principles serving as effective action-guiding tools to guard against (policy) inaction, procrastination, or recklessness. Given the fact that risks that are sufficiently harmful and sufficiently likely to fulfil the antecedent of a precautionary principle typically accumulate over time, precautionary principles are only effective if they constrain an agent's decision-making over time. On the basis of this observation, I argue for two claims. First, to yield the normative verdicts proponents of precautionary principles would like to make, precautionary principles must be understood to be diachronic principles, which requires some added structure to how they are commonly formulated. And secondly, such diachronic precautionary principles invite policy procrastination and inaction in their own right, due to both the vagueness of thresholds of harm and likelihood, and because agents will often fail to abide by the principles if they ignore bygone risks.

1 Introduction

Policy-makers ought to make laws aiming to phase out or restrict activities that could plausibly lead to catastrophe. Individuals ought not engage in activities that pose a significant threat to the lives of others. Prudentially, they should not make choices that come with a substantial risk of financial ruin. Precautionary principles such as these are frequently appealed to both in policy-making and in discussions of good individual decision-making. They prescribe omission or reduction of an activity, or taking precautionary measures, whenever potential harmful effects of the activity surpass some threshold of likelihood and severity.

In the policy context, precautionary principles can come to clash with what is often regarded as the gold standard of policy evaluation, namely risk-cost-benefit analysis. In risk-cost-benefit-analysis, for each policy option, we add up all potential costs and benefits, weighted by the probability with which we take them to occur. In contrast, when applying a precautionary principle, once we have determined that a potential harm stemming from an activity is serious and likely enough, the potential benefits that may come from taking the risk are disregarded. The activity should be avoided, restricted, or precautions should be taken, even if the potential benefits of the activity or the costs of precaution are substantial. According to proponents of precautionary principles, this is just as it should be: They take risk-cost-benefit analysis to be insufficiently precautionary.

A parallel observation applies to precautionary principles in individual decision-making and the orthodox theory of rational choice in the context of risk and uncertainty, expected utility theory. Under the standard interpretation, expected utility theory asks agents to take into account their evaluation of each of the potential outcomes of a proposed act by weighting it by its probability. In contrast, when we apply a precautionary principle, once we have determined that some particularly harmful potential outcomes are likely enough, it no longer matters how good all other potential outcomes are: The action should not be performed, or at least not without taking potentially costly precautions. To those who are sceptical of expected utility theory as a theory of individually rational choice for being insufficiently permissive of risk averse attitudes, this could be an advantage. In the moral context, deontologists, in particular, are often sceptical of attempts to incorporate expected utility theory when determining our moral obligations under risk. Precautionary principles appear to be promising ways of expressing deontological restrictions in the context of risk and uncertainty.¹

Given the centrality of precautionary principles in public policy discussion (in particular in environmental policy and the regulation of new technologies)² and their appeal in

¹Indeed, as I explore more in the following, there are several important insights in debates on deontology under risk in the ethics literature that are relevant for the discussion of precaution in the policy and individual context. Tenenbaum (2017), for instance, argues against what he calls the ‘multiplicative model’ for choice under uncertainty for deontologists, where the multiplicative model weights evaluations of the different consequences of actions by their probabilities. Instead, he proposes that deontological restrictions apply to act-types described in a way that incorporates their riskiness. For instance, he suggests ‘One may not endanger someone’s life except in order to secure a very significant good’ as a candidate deontological restriction in the context of uncertainty, where ‘endangering’ must be understood as posing more than a trivial risk to somebody else’s life (p. 697). This principle has the structure of a precautionary principle. Others have been more critical, e.g. Jackson and Smith (2006) who argue against such ‘threshold absolutism’, while acknowledging it might be the best way to approach risk and uncertainty from a deontological perspective.

²Discussion of precautionary principles arose in the context of German environmental policy in the 1970s, under the name of the *Vorsorgeprinzip*. It was first adopted into German law in 1974, in the *Gesetz zum Schutz vor schädlichen Umwelteinwirkungen durch Luftverunreinigungen, Geräusche, Erschütterungen und ähnliche Vorgänge* (Bundes-Immissionsschutzgesetz – BImSchG), §1.2. Internationally, precautionary principles rose to prominence when they were discussed at the International Conference on the Protec-

the individual realm, precautionary principles deserve serious consideration as principles of choice in the context of risk and uncertainty, constraining or supplanting the application of risk-cost-benefit analysis and expected utility theory. I will be concerned with three desiderata for precautionary principles in the individual and policy-making context: First, precautionary principles should not make grossly implausible recommendations. Second, precautionary principles should provide useful action-guidance to agents, that is, it should be easy for agents to work out what the principle requires them to do or not do. And third, precautionary principles should be *effective* action-guiding principles, by which I mean that agents who have accepted the normative authority of a precautionary principle and worked out what it recommends should not find it overly difficult to go through with its recommendations. The first desideratum is essential. The second and third need not be, depending on the purpose for which one is proposing the precautionary principle – after all, there are many moral principles that are imperfectly action-guiding, and expected utility theory itself is arguably too complex to implement to be effectively action-guiding. If the only purpose of precautionary principles was to express true moral principles within a deontological framework, or to express true principles of rationality that capture greater risk aversion, it may be desirable, but not important that these principles are themselves effectively action-guiding. Their implementation can potentially be dealt with separately, through action-guiding rules of thumb. However, the second and third desiderata are crucial for what I take to be the core purpose of precautionary principles in the public policy context, namely, to be effective decision-making and legal tools to guard against procrastinating on or altogether failing to confront and mitigate certain kinds of risk.

In the policy realm, precautionary principles are most frequently invoked to guard against risks that are hard to quantify – because the harm is very unlikely, because the scientific evidence on the possibility and likelihood of harm is yet slim, or because the potential harms stem from radical changes to human and non-human life that we find it hard to evaluate – and whose quantification there is consequently little agreement on. These risks may be very important to consider for a policy-maker. Yet, not being able to precisely quantify the potential harms and benefits of an activity and their likelihoods is a serious obstacle to conducting traditional risk-cost-benefit analysis. And lack of agreement

tion of the North Sea in 1984 and 1987, and influenced the Ministerial Declarations resulting from the conferences. In 1992, two important events enshrined precautionary principles as guiding principles for environmental policy both internationally, and in many nations world-wide. First, the EU made reference to ‘the’ precautionary principle in its founding document, the Maastricht Treaty. Second, the *Rio Declaration* following the United Nations Conference on Environment and Development in Rio de Janeiro advocated the “precautionary approach” to the management of forests. Precautionary principles have since been appealed to in contexts as diverse as climate change mitigation, (a precautionary principle is referred to in the latest IPCC (2014) ARC-5 WGII report), approval of medical trials, regulation of chemicals and new technologies, preemptive warfare (George W. Bush’s justification of the invasion of Iraq, which pointed to the possibility of weapons of mass destruction in the country’s possession, is often thought to be an instance of precautionary reasoning – see McLean et al. 2009), and protection of animal welfare (see Birch 2017).

on correct quantification will decrease the public credibility of any attempted evaluation. While there may be ways to extend the traditional framework to incorporate imprecise values and probabilities, there is a temptation in practice to simply ignore those risks we find it hard to quantify. This temptation will be even greater when there is reason to think that the state of our knowledge regarding the risk will improve over time, making a ‘wait and see’ strategy attractive. Proponents of precautionary principles worry about this appeal to lack of scientific knowledge and quantifiability serving as an excuse for either dangerous policy procrastination, or a reckless inattention to those risks whose quantification is difficult or controversial.³ In the individual context, too, there can be a temptation to use the fact that certain risks are hard to evaluate precisely as an excuse for delay, inaction or recklessness.

The advantage of precautionary principles, by contrast, is that they seem not to be as vulnerable to this excuse. All they apparently require for their application is a determination of whether the potential harms from an activity pass some, usually vaguely defined, threshold of severity and likelihood. This determination is often much less controversial than any particular risk-cost-benefit or expected utility analysis would be. For instance, while there is an overwhelming consensus in the relevant scientific community that there is a plausible mechanism by which current levels of global CO₂ emissions can lead to catastrophe if maintained, there is little agreement on the precise social cost of carbon. If determining the former is sufficient to yield a clear prescription to severely restrict activities that produce CO₂ emissions, then there is much less room for excuses to delay action than if any action needed to be backed up by a risk-cost-benefit analysis. For this reason, in fact even those who take some variant of risk-cost-benefit analysis or expected utility theory to be the true measure of the value of policy options might support some precautionary principles as action-guiding principles for pragmatic purposes in certain contexts.⁴ But precautionary principles will only serve as effective tools against policy procrastination, inaction or recklessness in the face of risk if they are effectively action-guiding.

In the following, I explore an important obstacle for precautionary principles fulfilling the role of effective and plausible action-guiding principles in the face of risk and uncertainty. My starting point here is the following observation: The kinds of risks that precautionary principles are meant to guard against rarely arise as the consequence of one single choice. On the policy scale, if, or sadly rather when the consequences of catastrophic climate change occur, this is and will be the result of decades of repeated failure to take preventative action by policy-makers, corporations and individuals around the globe. If

³In fact, one famous early statement of the ‘precautionary approach’ to public policy, namely that found in the 1992 Rio Declaration, defined the approach as ruling out using scientific uncertainty as a reason to postpone precautionary measures.

⁴For a recent defence of this idea, see Christiansen (2019).

a country's drinking water becomes polluted enough to pose serious health risks, this is likely the result of various different contaminants released into the water through various different pathways, and the responsible policy-maker's failure to adequately regulate each of them. If the commercial or political use of advanced neuro-technology came to undermine our basic rights to freedom of thought and privacy, this would be the result of an extended process of research and development, approval and implementation of many different technologies, which could have been restricted at various points in time and in various different ways. If a country fails to contain the spread of a deadly virus, this is likely the result of multiple failures of policy and logistics at many levels and over an extended period of time. On the individual scale, serious risks to one's own and other people's health and lives are often the result of repeatedly engaging in dangerous or unhealthy activities.

Given the fact that risks that are sufficiently harmful and sufficiently likely to fulfil the antecedent of a precautionary principle typically accumulate over time, those advocating precautionary principles need to explain how the principles are meant to effectively govern decision-making over time. I will argue for two claims in the following. First, to yield the normative verdicts proponents of precautionary principles would like to make, precautionary principles must be understood to be diachronic principles, which requires some added structure to how they are commonly formulated. And secondly, such diachronic precautionary principles invite policy procrastination in their own right, due to both the vagueness of thresholds of harm and likelihood, and because agents will often fail to abide by the principles if they ignore bygone risks. Therefore, carefully formulated precautionary principles might be useful as normative background principles that, in the policy context, can enjoy wide public support, but are less likely, on their own, to be effective tools to counter (policy) inaction, procrastination or recklessness in the face of risk.

2 Precautionary Principles

The most frequently cited appeals to a precautionary principle, such as the 1998 Wingspread Declaration, or the Maastricht Treaty, refer to 'the' precautionary principle in the singular, and intend it to apply to a wide variety of both individual and policy choice contexts where harms to human health or the environment are at stake. However, it has also been acknowledged that more specific formulations of the principle are needed for a precautionary principle to offer substantial action-guidance to individuals and policy-makers. And there seems to be a broad agreement amongst proponents of precautionary principles today that different kinds of precautionary principle are appropriate for different contexts. In particular, proponents of precaution typically accept that the

urgency of precaution, and the kind of precaution required will depend on the severity of potential harm. Where the survival of mankind is at stake, less evidence of risk should be required to take precautions than when we are ‘merely’ facing a regional, non-lethal health hazard (Sandin 2006). Hartzell-Nichols (2013) has consequently proposed that we should no longer speak of “the” precautionary principle, but rather of precautionary principles in the plural, all of which are instances of a “precautionary approach”, or precautionary reasoning. I will follow this use here.

What matters for our purposes is that most precautionary principles proposed in the literature share some common structure, and are meant to express the spirit of precaution in the face of uncertain harms – of being risk averse, and being ‘rather safe than sorry’. The shared structural features of precautionary principles that I am concerned with here are the following:

1. There is a threshold of likelihood and/or severity of potential harm caused by one’s activities beyond which precautionary measures (e.g. omission) are required.
2. This threshold is/these thresholds are vague. That is, they allow for borderline cases that do not clearly fall above or below the threshold.
3. The principle does not specify explicitly the scope of the activity it is meant to be applied to. In particular, it is not made explicit whether the principle is meant to be applied to small-scale individual choices, or also to entire courses of action over time, and if the latter, to how long and comprehensive a course of action.

Consider the following three examples of precautionary principles:

- a. The option with the best worst-case outcome that meets some minimal level of plausibility should be chosen (Hansson 1997).
- b. “If a scientifically plausible mechanism exists whereby an activity can lead to a catastrophe, then that activity should be phased out or significantly restricted.” (Steel 2014, p.28)
- c. “One may not endanger someone’s life except in order to secure a very significant good.” (Tenenbaum 2017, p. 697)

Each of these principles clearly shares features (1), (2) and (3) above. (a) is a maximin principle, but one that only takes into account risks that pass a vague threshold of likelihood.⁵ (b) refers to a vague threshold of harm, namely ‘catastrophe’, that needs to be met

⁵Several early formal analyses of ‘the’ precautionary principle interpreted it as a maximin principle, as

for us to be required to phase out or significantly restrict an activity that might cause it. Moreover, ‘scientifically plausible mechanism’ is at least in part a threshold of likelihood. (a) and (b) are meant to be applied to ‘options’ and ‘activities’ respectively, leaving the scope of the activity unspecified. (c) rules out ‘endangering’ somebody else’s life, unless a very significant good is at stake. Tenenbaum proposes that an act only counts as ‘endangering’ once it poses more than a trivial risk to somebody else’s life (p. 697), that is, once it passes a vague threshold of likelihood of harm, which may also be sensitive to context. The required precaution once this threshold is crossed is omission of the activity. The principle itself does not make reference to the scope of the activity it is meant to apply to.⁶

There are also good reasons why these principles share at least features (1) and (2). Vague thresholds of likelihood such as the one in (a) are often defended as an application of a ‘de minimis’ rule, which is a principle that entered more traditional risk-cost-benefit analysis in the 1980s. In that time, the FDA started explicitly treating some risks, such as a one-in-a-million lifetime risk of death from exposure to a substance, as ‘negligibly small’, and excluding them from analysis.⁷ As Hansson (1997) argues, *de minimis* conditions make sense for precautionary principles for two reasons. First, the strict worst-case consequences of all options available to us are arguably equally catastrophic:

Logically speaking, any decision may have unforeseen catastrophic consequences. If far-reaching indirect effects are taken into account, then – given the unpredictable nature of actual causation – any decision may lead to a nuclear holocaust. Any action whatsoever might invoke the wrath of evil spirits (that might exist), thus drawing misfortune upon all of us. (Hansson 1997, p. 300)

And, second, even if we did have options that completely rule out such extremely unlikely worst-case scenarios, this may detract from precautions that are intuitively more important. For instance, in the policy context, if we judge that the immediate annihilation of all life on Earth through collision with a large asteroid is worse than the worst-case consequences of global climate change, then a maximin principle without a *de minimis* clause would recommend spending a massive amount of resources on asteroid impact avoidance, which could otherwise be used for climate change mitigation and adaptation.⁸

Hansson (1997) does here. While Hansson is ultimately critical of his proposed version of the precautionary principle, Gardiner (2006), e.g., offers and defends a similar ‘Rawlsian’ version of the precautionary principle.

⁶As we will see below, Tenenbaum in fact intends it to apply to any scope of activity.

⁷See Comar (1979) for an early defence.

⁸A *de minimis* condition has been defended by various other proponents of precautionary principles. Some critics of the precautionary principle have attacked a naive ‘catastrophe principle’, which proposes taking precautions against any event or activity that has any possibility of leading to (personal or collective) catastrophe. Clearly, such a principle would be extreme in requiring us to take precautions against all

To address the full range of policy issues and individual choice contexts where precaution is typically recommended, many precautionary principles appeal to thresholds of likelihood that are not *de minimis* conditions (capturing when a risk is negligible), but instead specify potentially higher thresholds of likelihood past which some harm mandates special kinds of precautionary measures. As (b) and (c) exemplify, many precautionary principles have what Steel (2014) calls a ‘tripod structure’.⁹ This tripod structure specifies a harm condition (a degree of seriousness of harm), a knowledge condition (a state of knowledge we have about the potential harm occurring), and a precautionary measure that is proposed if the harm condition and the knowledge condition are met. This structure then allows us to express what appropriate precaution amounts to in a particular context. For instance, (b) is proposed by Steel (2014) as plausibly applicable to climate change mitigation. In this case, the harm condition is that there is a risk of catastrophe, the knowledge condition is that there is a scientifically plausible mechanism by which an activity leads to the harm, and the proposed remedy is that the activity be phased out or significantly restricted. Clearly, all precautionary principles that share this tripod structure will share feature (1) above, since they specify a harm and knowledge condition after which precaution is recommended.

Insofar as they are precisely formulated, a common worry about *de minimis* rules and other thresholds of likelihood and harm is that they are arbitrary.¹⁰ There seems to be no important difference between a one-in-a-million lifetime risk of death from a substance and a one-in-a-million-and-one risk. Yet, strictly speaking, this would make all the difference for FDA regulation. In the deontology under risk literature, the arbitrariness of thresholds in deontological principles that take the form of precautionary principles is also often criticised (e.g., by Jackson and Smith 2006). In response to the arbitrariness worry regarding *de minimis* clauses, Peterson (2002) argues that we should acknowledge that the *de minimis* condition is in fact vague, and will thus have borderline cases. As in other cases of vagueness, this does not mean that there aren’t clear cases of risks that are or are not *de minimis*.

A more important reason for the vagueness of thresholds is that characterisations

sorts of remote possibilities. As Munthe (2011) notes, it would be absurd to take precautions against a 1-in-19 billion lifetime risk of developing cancer from a food additive. Moreover, the catastrophe principle has been argued to be incoherent, since any precautionary measure itself has the possibility of leading to catastrophe. This was argued most prominently by Sunstein (2005). Amongst others, Sandin et al. (2002), Peterson (2002), Clarke (2005) and Steele (2006) respond to these worries by defending a *de minimis* clause. However, note that, as Steel (2014) points out, merely introducing a *de minimis* clause does not do away with the possibility of incoherence, since whatever the *de minimis* condition is, there may still be cases where a recommended precaution itself has potential harmful effects that are not themselves *de minimis*.

⁹See also, e.g., Cranor (2001), Manson (2002), Munthe (2011), Steel (2014). Sandin et al. (2002) add a 4th dimension, namely the force with which the precaution is recommended.

¹⁰Besides Hansson (1997), see also Shrader-Frechette (1985).

of thresholds of likelihood and harm in precautionary principles often refer to qualitative concepts that simply are vague. For instance, Hansson (1997) proposes “scientific reasonableness” as a *de minimis* condition (p.300). Tenenbaum (2017) aims to rule out “endangering” lives. Examples of alternative harm conditions are that consequences are ‘serious’, ‘harmful to humans’, ‘irreversible’, or ‘such as to reduce or eliminate biodiversity’ (Manson 2002). There are evidently borderline cases of ‘scientific reasonableness’, ‘endangering’, ‘serious’ harm, or of ‘catastrophe’. Yet, these vague concepts may be the normatively most relevant categories for a particular context. Even when we put some effort into defining these conditions more precisely, it will be difficult to eliminate vagueness altogether. For instance, Hartzell-Nichols (2012) defines ‘catastrophic’ outcomes as those “in which many millions of people could suffer severely harmful outcomes.” (2012, p. 160) This is helpful in understanding what a catastrophe is, but clearly both “many millions of people” and “severely harmful outcomes” admit of borderline cases themselves. That they feature vague thresholds of likelihood and/or harm, and therefore fulfil conditions (1) and (2) above, thus seems essential to precautionary principles as they are most commonly discussed.

Finally, it helps to remember that precautionary principles are often invoked in cases of deep uncertainty, where we cannot assign precise probabilities to all outcomes, perhaps because we lack conclusive scientific evidence, or cannot precisely evaluate the potential harms involved. If our judgements of likelihood or of harm are imprecise,¹¹ then even if we were to formulate a precise likelihood or harm threshold, there will be borderline cases. This is because for some risks, it will not be clear whether they fall above or below the harm or likelihood threshold. The presence of such borderline cases, even if thresholds were precise, is enough to trigger the problems stemming from vagueness that I will discuss in the following.

3 Two Problems

I have shown that typically, precautionary principles specify a vague threshold of harm and/or likelihood beyond which precaution is required. The core challenge I want to raise here is that this makes it possible that we find ourselves in situations where many different actions together result in a risk of harm severe enough to trigger the application of a particular precautionary principle, while no individual action seems to do so. Since, as we just saw, precautionary principles tend not to specify the scope of activity they are meant to apply to, this results in two problems. First, which scope or scopes of activity

¹¹Imprecision in credences is often represented with a family of probability functions. This can lead to borderline cases of the application of a precautionary principle when some members of this family assign a probability above the threshold, and others below the threshold.

should the precautionary principle be applied to? I will refer to this as the ‘problem of scope’. And second, can precautionary principles effectively govern an agent’s decision-making over time? I will refer to this as the ‘problem of execution’. To illustrate, consider the following three stylised examples of individual decision-making.

Investing in Your Friends’ Startups. Your 100 friends want you to invest in their 100 startups. You judge that for each, the chance of failure is non-negligible. But you wouldn’t lose much money on each, and the expected payoff from each investment is positive. Moreover, you like to help out your friends. And so much speaks in favour of investing in each. You also think that the probability of failure of the different startups is independent, and that it is very likely you would make an overall gain from investing in all. However, you know that it is still possible that all of the startups fail. This would mean financial ruin for you. You are a cautious person, and care deeply about avoiding financial ruin. You formulate the following precautionary principle:

PP-Investment: If there is a plausible chance that some choice leads to financial ruin, then I should not make that choice.

You judge that the antecedent is true for all 100 investments considered together: There is a plausible chance that all fail, which would lead to a clear case of financial ruin. At the same time, you judge that the antecedent is never true for any individual investment in a startup. The potential loss from each investment is small, and you judge that no individual added investment will ever turn the worst-case scenario for your overall portfolio from non-financial ruin into financial ruin.

Practising for a Piano Exam. You’ve been learning the piano for some years, and you are starting to think that you want to pursue a career as a professional pianist. A minimal condition for becoming a professional pianist is that you pass an upcoming performance exam. Passing the exam is thus crucial for your future life design. You are confident that you will pass it with sufficient practice, and that sufficient practice wouldn’t be so disruptive as to undermine any other important life goals. But you also know that if you don’t practise enough, there is a substantial chance that you will fail the exam. You judge that generally speaking, practising more raises the chance of you passing your exam. But each time slot that you could use for practice could also be used for more immediately pleasurable activities, say, playing a computer game. You see a danger that you might fail to practise sufficiently for your exam, spending lots of time gaming instead. As a cautious person, you formulate this precautionary principle:

PP-Piano: If an activity with no lasting importance to me leads to a substantial

chance that I will fail my piano exam, I should not engage in it.

Gaming has no lasting importance to you. And spending any available practice time slot before your exam gaming instead of practising would certainly lead to a substantial chance that you will fail the exam. And so the antecedent of this precautionary principle would hold true when considering the activity of gaming in all practice slots. However, it does not seem to hold true when considering gaming instead of practising on any individual occasion where you have an hour of available practice time: You judge that any one-hour practice session only has an insignificant and hard to identify effect on your chances of passing. In your estimation, no missed one-hour practice session takes you from a non-substantial to a substantial chance of failing.

Cycling to Work. You are deciding whether to cycle to work, rather than take the train. You conduct the following rough-and-ready risk assessment. In the UK, there were about 5,300 cycling accidents per billion miles cycled in 2018, which corresponds to an average risk of accident of 0.00053% per mile.¹² If your cycling style and route to work were representative and nothing relevant changed since 2018, you calculate that there would be a 0.004% risk of accident per return trip to work. This would result in a 0.96% risk of accident in a working year. Even though you know you are probably not representative in many ways, and conditions for cyclists change constantly, you at least judge that these probabilities are in the right ballpark. You care deeply about not getting into a cycling accident. Since you are a cautious person, you formulate the following precautionary principle:

PP-Cycling: If an activity leads to a non-negligible risk of accident, and there is a significantly safer but not significantly more costly alternative available, I should take the alternative.

While taking the train is an affordable alternative to cycling, if precaution is not a concern, you judge cycling to be certainly better than taking the train: You exercise, you see the city, you are not stuck on a claustrophobic commuter train, and it's better for the environment. So the important question is whether the antecedent of your precautionary principle holds true, that is, whether you judge the risk of a cycling accident to be negligible or not. Your problem now is the following: You judge that the risk of a cycling accident on any individual day (ballpark 0.0004%) is negligible. However, the risk of accident from cycling for an entire year (ballpark 0.96%) is certainly not negligible.

Each of these cases features what I will call an 'incremental activity', namely investing in one startup, missing one hour of practice, and cycling on one day respectively.

¹²see UK Department for Transport (2019).

They also feature an extended activity which consists in repeatedly engaging in the incremental activity. What makes these cases problematic is that in each case, the proposed precautionary principle constrains the agent, by prescribing omission,¹³ when applied to the extended activity, but doesn't constrain any of the incremental activities considered in isolation. At least this is so if we grant the judgement that no individual incremental activity can make the agent cross the harm or likelihood thresholds specified in the antecedent of the precautionary principle, an assumption I will call 'tolerance'. Risks of the seriousness and likelihood that the precautionary principle aims to guard against accumulate over time in such a way that only extended courses of action seem to be constrained by the precautionary principle.

Call any such case a 'cumulative risk case'. But note that the accumulation of the serious risk works differently in each of these cumulative risk cases. In the first case, it is the severity of potential harm that accumulates so that the harm threshold is only crossed when many incremental activities are considered together. Let us call such cases 'cumulative potential harm cases'.¹⁴ In the second and third cases, it is the likelihood of harm that accumulates, so that the likelihood threshold of the precautionary principle is only crossed when many incremental activities are considered together. Let us call such cases 'cumulative likelihood cases'. Moreover, these two cases are distinguished by the manner in which the likelihood of harm accumulates. In the cycling case, the agent faces many individual small risks, each of which is resolved before taking the next risk. By the time you decide whether to cycle tomorrow, you will already know whether today's cycling resulted in an accident or not. By tomorrow, today's risk is in that sense bygone – you are not facing it anymore. By contrast, in the piano case, the likelihood of the harm of failing your exam accumulates without resolution, and is only resolved at the end of a long series of choices. To distinguish these two types of cases, call cycling-type cases 'transient cumulative likelihood cases' and piano-type cases 'aggregating cumulative likelihood case'.

All three types of cases also seem to occur in policy contexts, though most real applications will of course be more complex than our stylised examples. For instance, the approval of clinical trials, decisions about road safety, or the continued operation of nuclear power stations seem to exhibit a similar pattern to the cycling case and could be analysed as transient cumulative likelihood cases, where the risks of incremental activities, or of the continuation of a policy, are continuously resolved. Research into technologies with

¹³The following discussion of the problem of scope will apply equally for other kinds of prescribed precaution (e.g. taking out insurance, wearing a helmet). As noted below, in the case of the problem of execution, some precautionary measures are not quite as prone to the problem as omission.

¹⁴Note both the similarity to and the distinction from the much discussed 'collective harm cases' (see Nefsky 2019 for an overview), sometimes also referred to as 'cumulative harm cases'. In collective harm cases many actions carried out by many different people together cause a severe harm *for certain*, but no individual choice seems to make a difference. Here many choices by the same agent together make it the case that the harms in a sufficiently likely worst-case scenario are severe enough to cross the vague harm threshold of a precautionary principle, but no individual choice seems to do so.

potential dual use, continuation of the activities that raise the probability of a runaway greenhouse effect, continuation of activities that provoke a hostile state, or loosening of restrictions during a global pandemic might involve a pattern similar to the piano exam case. As research results, emissions, memory of provocations, and opportunities for close contacts aggregate, at least for the relevant foreseeable future, these cases can involve an ever increasing likelihood of a severely harmful outcome at a later point in time. They could thus be analysed as ‘aggregating cumulative likelihood cases’.¹⁵ Lastly, climate change mitigation more generally also appears to involve a similar pattern to the investment case, where the worst-case scenarios involve extreme harms only because of many small-scale emissions decisions. To that extent, it can be analysed as a cumulative potential harm case.

As noted above, the judgement that the precautionary principles in our cases only restrict agents when applied to extended courses of action, and not when applied to incremental activities individually relies on a tolerance assumption: that incremental activities can’t make an agent cross the harm or likelihood thresholds of a precautionary principle. I take this tolerance assumption to be especially plausible in the case of transient cumulative likelihood cases, as here tolerance can be justified independently of the vagueness of the thresholds. This is because in transient cumulative likelihood cases, the risk already incurred through past choices is bygone, already resolved. This makes it very plausible that it is irrelevant for the evaluation of the next risky choice. The risk incurred in the next choice is not in any meaningful sense adding to some growing likelihood of harm (as is the case in the aggregating cumulative likelihood cases). If no accident has happened so far, and past risk has been resolved, the next risky choice only brings about a negligible risk for the agent, which supports the tolerance assumption.

In the other two cases, tolerance is plausible because of the vagueness of thresholds. In these cases, potential harm and likelihood aggregate without resolution. When we are yet far from reaching a threshold of harm or likelihood, another incremental activity won’t make an agent cross it, and when it has already been crossed, another incremental activity is not what causes the substantial risk, and is thus not ruled out by the precautionary principle. However, in the borderline region, tolerance only seems plausible because, in the face of a vague threshold, incremental activities seem to make too insignificant a difference to, e.g., turn potential worst-case losses from non-financial ruin to financial

¹⁵However, real-life examples like this will also be more complex than the piano case in the sense that there is no one fixed point in time at which the dice will be thrown, as it were. Rather, once enough research, greenhouse gases, provocations, and opportunities for close contact have amassed to make the harm in principle plausible, there is some probability of research being used for harmful purposes, a runaway greenhouse effect being triggered, armed conflict breaking out, or exponential growth of infections at any point in time, and that probability increases through the continuation of the activity, and stays increased for some time. To the extent that a harmful effect could arise any day, and when it doesn’t, that risk is bygone, such cases also exhibit the characteristics of transient cumulative likelihood cases.

ruin. If the tolerance assumptions in the above cases do not seem intuitively plausible, we can always individuate the incremental activities even more finely, e.g. considering only a fraction of an investment, one minute of missed practice time, or another minute of cycling. That tolerance assumptions for small enough incremental changes seem intuitively very plausible is indeed a characteristic feature of vague predicates – this is what makes the Sorites Paradox a paradox.

Insofar as the efficacy of precautionary principles as action-guiding principles is concerned, the intuitive implausibility of denying tolerance is arguably already enough to make us doubtful that precautionary principles would *effectively* constrain individuals when applied only to incremental activities: The effectiveness of the principle would rely on agents identifying some specific incremental activity that brings them, e.g., from a case of potential of only non-ruinous financial harms to potential financial ruin, which seems too much to ask in practice. Nevertheless, motivated by aiming to resolve the Sorites Paradox, some theories of vagueness deny the truth of tolerance assumptions for vague predicates, in which case it might seem that, at least in theory precautionary principles may constrain incremental activities. In response to this concern, the Appendix argues that at least the three major theories of vagueness either don't support the idea that precautionary principles constrain some incremental activities considered individually, or would only do so under some strong additional assumptions.

I will thus take the intuitive analysis of our cases for granted, and moreover assume that a similar analysis applies in real world cases that share a similar structure, such as the policy applications considered above. For instance, a precautionary principle aiming to constrain activities that bring about a non-negligible chance of a catastrophic accident would only constrain the operation of nuclear power stations over long stretches of time, and not the activity of operating them for one more day considered in isolation. A precautionary principle aiming to constrain activities that bring about a plausible chance of human extinction in the next few hundred years would only constrain CO2 emitting activities on a global scale considered over many years, but would not constrain incremental emitting activities considered in isolation. We can now formulate the problem of scope and the problem of execution more precisely.

The problem of scope arises because in the kinds of examples we considered, the scope of activity to which we apply the precautionary principle makes a difference. When we treat each individual investment, hour of practice missed or commute as a separate activity and only apply the precautionary principle to those incremental activities, we come to a different conclusion about what the agent should do than when we bundle many commutes or investments together in a larger choice problem, and apply the precautionary principle to this extended course of action. If we do the former, the agent is unconstrained by the precautionary principle, and free to engage in each incremental activity (which we

assumed the agent would indeed do if unconstrained). If we do the latter, the agent is constrained not to engage in each incremental activity. Fixing the level(s) of scope at which the principle applies in different ways leads to divergent recommendations. If that is so, how should precautionary principles be applied?

On top of this problem of scope, a problem of execution arises in our cases. Suppose that we have established that a precautionary principle should be applied at the level of a temporally extended activity. In the cycling example, suppose I apply the proposed principle to my choice of method of commute for at least one year. I thus determine that I should not cycle on each individual occasion. Instead, I should cycle on few enough occasions that the risk of a cycling accident over the course of the year remains negligible. The execution problem arises because this decision still has to be implemented over time. Below, I will argue that the fact that, in our examples, no incremental activity can ever trigger the relevant precautionary principle is an obstacle to effective implementation.

4 The Problem of Scope

When, as we have seen, the scope or scopes of activities at which precautionary principles are applied makes a difference to what they recommend, how should the principles be applied? In the following, I will present some potential responses to the problem of scope, and eventually argue for the last one. If precautionary principles are to effectively guard against serious risks, they must be applied to extended series of choices over time in the kinds of examples we considered. But to do so in a way that has no implausible implications, some additional structure is needed in the way in which precautionary principles are typically formulated.

4.1 Denying the Problem

The last section already addressed one potential reason to deny the problem of scope exists, namely denying the tolerance assumption underlying the judgement that incremental activities are unconstrained when considered in isolation. Another potential strategy for denying the problem starts from the observation that most proponents of precautionary principles argue that different principles are appropriate for different contexts. The problem of scope could potentially be avoided if we successfully argue that different precautionary principles are appropriate when considering incremental activities or extended activities respectively. What we would need to show, in order to rule out the problem of scope (as well as the problem of execution), is that there is always a match between what the appropriate precautionary principle for the extended activity demands, and what the

precautionary principle for the incremental activities demands. However, I take this to be highly implausible in our examples.

Usually, differing precautionary principles for different contexts are justified by an appeal to proportionality: What evidentiary standards apply should be calibrated to what precautionary measures we are demanding and to the severity of the potential harm in question.¹⁶ Harm condition, knowledge condition and remedy should be chosen so as to express an appropriately precautionary attitude for the circumstances in question. In our cycling example, the harm we are concerned with is the same whether considering individual choices or a longer term activity: I do not want to be involved in a cycling accident. However, the proposed remedy in the individual case is less costly: It involves refraining from cycling just once, as opposed to many times. And so perhaps the knowledge condition can be less stringent in the individual case, so that the remedy is demanded even for a much less probable risk of accident – as low as the very low risk from only cycling once.

The problem with this response is that it implies that appropriate precaution would demand not engaging in the incremental activity even in circumstances where I face a truly one-off choice of whether, e.g., to cycle to work or not. But that seems highly implausible: The risk on any one occasion really does seem negligible, and deciding not to cycle due to that risk, on a one-off occasion, seems overly cautious. Indeed, it is only when we start considering the consequences of cycling regularly that serious concerns about the risks of accident arise.¹⁷ The same holds for the investment and piano practice decisions. A real-world application similar to the cycling case where such judgements are commonly expressed is the debate around the potential dangers from radiation from backscatter x-ray scanners used in airport security.¹⁸ The dosage of radiation from these scanners is low (much lower than the radiation from a medical x-ray scan), only to the surface of the body, and exposure is very short. But in theory, the radiation from each occasion of a backscatter x-ray scan could cause cell damage which could lead to cancer (Accardo and Chaudhry 2014). As in our cycling case, the most common models of the cancer risks from radiation assume that each backscatter x-ray scan exposes passengers to an independent risk of developing cancer (Mehta and Smith-Bindmann 2011). The EU banned backscatter x-ray scanners at airports in 2012, which may be interpreted as an application of the precautionary approach the EU is committed to. However, the justification of the ban was that at that point, a superior technology was available, which only exposed passenger to non-iodizing radiation – suggesting that the ban would not have been implemented if the costs to precaution had been higher (Grabell 2011). When it comes to advice to individual passengers, even the most concerned medical professionals only recommend

¹⁶See, for instance, Steel (2014), and Whiteside (2006).

¹⁷Also see Tenenbaum (2017), p.13 for this analysis of the cycling example.

¹⁸I thank Sergio Tenenbaum for this example.

refusing x-ray scans, and opting for a physical pat-down instead, to those especially at risk, and, importantly for us, frequent fliers (Brenner 2011). As in the cycling case, their reasoning is that a very low risk only becomes a concern when we take it repeatedly, even though the risk on each occasion is independent from the risk on the next.

What does this mean for the response that, if we use the appropriate precautionary principle for each context, we will not get conflicting recommendations in the cases we are concerned with here? In these cases, refusing to take the one-off risk is not the proportionate precautionary reaction to the risk faced on one occasion. If precaution demands refusing the risk it is only because the agent faces the risk repeatedly. And so, if the appropriate precautionary principle for the context of my incremental cycling decision is such that it recommends not cycling, it is the diachronic context of my past and future choices that makes it so. However, arguing that the diachronic context makes a difference in this way seems to be just another way of giving priority to precautionary principles applied to extended courses of action. And this is a way of having addressed the problem of scope, not a way of denying its existence.

4.2 Accepting Frame Dependence

Another reaction to the problem of scope might be that any agent is simply free to frame her decision problems as she sees fit, and should only apply the relevant precautionary principle to the decision as she framed it. For instance, in the investment case, you could either consider investing in each startup as a separate investment, or you could consider yourself as facing just one investment decision of how many and which startups to invest in. If you consider yourself as facing just one large investment decision, then *PP-Investment* will tell you not to invest in all startups, since that would bring with it a plausible chance of financial ruin. Instead, you should invest in few enough of the startups to rule out the possibility of financial ruin. What if you consider investing in each startup as a separate investment decision? Applied to each of those incremental activities separately, the precautionary principle does not recommend against investing. You are then free to invest in each, as we said you otherwise prefer.

There is in fact evidence that people's investment decisions can differ strongly depending on whether they are prompted to think of more long term or more short term returns, and so this frame dependence actually captures how many of us make decisions under risk and uncertainty.¹⁹ However, we typically think of this kind of frame dependence as problematic. In the kinds of contexts we are considering, if precautionary principles were only ever applied to the frame the agent chose, framing would make all the difference for how much precaution is actually recommended by the relevant precautionary principle.

¹⁹See Benartzi and Thaler (1999).

In fact, an agent prone to narrowly framing her decisions would not see her actions constrained very much at all by precautionary principles. But then those principles would not be doing their intended job as effective tools against (policy) procrastination, inaction, or recklessness. Moreover, it is counterintuitive that what an agent morally or prudentially ought to do should depend on a framing decision – unless, that is, there is a matter of fact about which frame an agent morally or prudentially ought to choose. But what the right scope of activity is to apply precautionary principles to is just the original problem of scope.

4.3 Rejecting Precautionary Principles Due to Insurmountable Inconsistency

Another reaction to the problem of scope might be that in the kinds of examples we considered, precautionary principles lead to a problematic inconsistency in recommendation that ultimately counts against precautionary principles. In our cases, it might look like the agent ought to do incremental activity x_1 , and she ought to do incremental activity x_2 , and x_3, \dots but she ought not do (x_1 and x_2 and x_3, \dots). For instance, in the investment case, it might seem like you ought to invest in each of your friends' startups, but also that you ought not invest in all of them. In the cycling case, it might seem like you ought to cycle on each day, but you ought not cycle every day. Proposed deontological rules for choice under uncertainty are often criticised for such alleged failures of agglomeration.²⁰ However, this worry can be easily dealt with in our cases. The analysis that there is an inconsistency is in fact based on assuming two inconsistent answers to the problem of scope. The inconsistency disappears once we settle on one answer.

The verdict that you ought not invest in all of your friends' startups (or not cycle to work every day) relies on applying the respective precautionary principle to the extended activity. However, the verdict that you ought to invest in each of your friends' startups (or cycle on each day) relies on your *only* applying the precautionary principle to each incremental activity separately: In that case, the precautionary principle does not constrain you, and you are free to choose what an ordinary weighing of costs and benefits would recommend – and I grant in that case you ought to engage in the incremental activity. If you were to *also* apply the precautionary principle to the extended activity in addition to each incremental activity, this might very well constrain what you should do on each day, as the precautionary principle then places restrictions on what series of action you may perform. The perception of inconsistency thus arises from an inconsistent answer to the problem of scope. If we answer it consistently, the inconsistency in recommendation disappears. We can either apply it just to incremental activities, in which case it is not

²⁰See, in particular, Jackson and Smith (2006). My response here mirrors that of Hawley (2008) to Jackson and Smith.

true that you ought not perform all incremental activities in a series. Or we could apply it also (or only) to the extended activity, in which case it is not true that you should perform each incremental activity. The question we need to answer is at what scope or scopes the principle should be applied.

4.4 Applying Precautionary Principles at Large Scopes

To those who have recognised the problem that risks which we are genuinely concerned about are often the result of taking many small risks that are individually judged *de minimis*, it has often seemed obvious that precautionary principles should be applied to extended activities. Mumpower (1986), for instance, writes:

A level of risk that is not of concern in any single instance may be viewed quite differently if it is part of an ongoing cumulative series. [...] This point underlines the importance of evaluating proposed *de minimis* (or any other risk management) schemes on the basis of the portfolio of risks that would accumulate over time from such a scheme, not on the basis of the apparent reasonableness of any single instance of its application. (p. 442)

Similarly, Hansson (1997) suggests that we should, in such cases, individuate our actions as one large decision problem (though he points to some practical problems for doing so), and Steele (2006) argues that we should “situat[e] any particular course of action within the broader field of actions that have similar consequences.” (p. 22) Given the purpose of precautionary principles is to effectively guard against significant risks, and a risk is no less significant just because it is generated cumulatively, this is a natural response. For precautionary principles to do their intended jobs, it seems like they must be applied to extended activities.

In the deontology under uncertainty debate, Tenenbaum (2017) has suggested that deontological restrictions taking the form of precautionary principles, such as the requirement not to endanger the lives of others, should simply be applied to every scope of activity an agent is (considering) engaging in. After all, if I am a bad and frequent driver, driving badly on a particular day, and driving badly every day for a year are both things that I do. The precautionary principle could be thought of as potentially restricting all of my activities. If the latter endangers others, then the precautionary principle might demand that I don’t drive at least on some days, even if no individual day of driving on its own would count as endangering others.

A common response to the problem of scope is thus that precautionary principles should be applied at a large, or even at all scopes. Indeed, precautionary principles

could potentially be applied to all of an agent's risky lifetime choices taken together. Let me call this the 'global' scope. Precisely what the global scope for a policy-maker would be depends on questions of agential perspective that are often left vague in debates about precaution:²¹ Are we specifying decision rules for regional, national or international policy-makers? And do we consider the policy-maker to have continuous agency throughout changes in government or constitution? Potentially, we could apply precautionary principles to all risky policy decisions facing a society for centuries to come all at once.

Suppose that the global scope was the or a right scope at which to apply precautionary principles. The problem now is that from that perspective, many kinds of precautionary principles that are standardly proposed in the literature are not plausible. Precautionary principles applicable to individual decision-making tend to state that if an activity carries with it some small chance of premature death or a severely harmful health outcome, then that activity should be avoided. Taking a global perspective, this principle would apply to the 'activity' of my entire life taken as a whole. But arguably any worthwhile way in which I could conduct my life will carry with it not only a small, but a substantial risk of premature death. Avoiding all potential causes of premature death is not only practically difficult, if not impossible, it is also clearly undesirable. In the policy case, precautionary principles tend to state that if an activity leads to a small risk of catastrophe or serious harm to many people, then that activity should be avoided. But the normal course of civilisation over centuries viewed as a whole will bring with it not only a small but substantial risks of various different kinds of serious harms. It is questionable whether a policy-maker should do everything in her power to make those risks negligible. For instance, adopting a science policy that would make the total risk of serious harms to human life and health from all scientific innovation expected to take place in the next 200 years negligible would likely be seriously restrictive to human progress.

We may be able to formulate thresholds of harm and likelihood that are more plausible at the global scope, in terms of the lifetime risk of premature death, or of other kinds of harm that an agent should not cross. For instance, one such precautionary principle may state that, if I can and this does not come with exorbitant costs, I should avoid a lifestyle that generates a substantial risk of premature death. We could, for instance, think of odds of roughly 1 in 10 as 'substantial'. In the policy case, such 'global' precautionary principles would specify vague thresholds for the overall risk of various kinds of harm that a society should not cross viewed over the course of its existence.

While these principles would avoid the problem of implausibility at the global scope, they would look quite different from the ones usually proposed in the literature and policy discussions, which generally warn against much smaller risks of harmful outcomes.. Moreover, they would only provide very limited action-guidance. The individual case pre-

²¹Also see Bradley and Steele (2015) on this issue.

cautionary principle just proposed could be adhered to in a myriad of different ways. The decision of whether to cycle to work or not, for instance, would certainly not be settled one way or the other by application of such a principle. While traffic accidents are one of the most common causes of premature death in the developed world, so are heart conditions. And the exercise I would get from cycling to work could be a good way of reducing my risk of developing a heart condition. Even activities that unequivocally and substantially raise the risk of premature death may not be ruled out by such a principle. I could regularly ride a motorbike without a helmet, as long as I make efforts to substantially reduce all other risks of premature death. The kinds of precautionary principles that would be plausible from a global perspective would thus rule out some lifestyles, but probably wouldn't rule out many particular kinds of activities.

Another way to avoid implausibility at the global scope would be to apply precautionary principles at large scopes short of the global scope, but not the global scope. But in that case where exactly should we stop? We can't just instruct agents to pick the level of individuation that gives the intuitively 'right' result, as then the precautionary principle doesn't do any action-guiding work. And it is hard to see what a principled general answer to that question could be.

4.5 Additional structure

There are at least two ways in which adding additional structure to precautionary principles can help us respond to the problem of scope. The first is to add a clause that makes it the case that the agent is no longer constrained by the principle in those cases where the principle's recommendation would otherwise be implausible at the global scale. The most promising strategy, I think, would be to restrict precautionary principles to constrain agents only in cases where taking a risk of the magnitude specified in the principle is not required for achieving some much more important goal, such as, in the individual case, living a fulfilling life, or in the policy case, achieving technological transformation that significantly improves the lives of most people on Earth. Note that Tenenbaum's principle, which we labeled (c) above, included such a clause: "One may not endanger someone's life except in order to secure a very significant good." (Tenenbaum 2017, p. 697). If we include such a clause, the precautionary principle could be applied at all scopes after all, but would not restrict agents in cases where the upsides of taking the risk are especially important.

A second way in which additional structure can help address the problem of scope is to make the scope of activity the principles are meant to be applied to explicit in the formulation of the principle. Consider, for instance:

*PP-Cycling**: If a series of commuting decisions over the course of any one-year period leads to a non-negligible risk of accident, and there are other significantly safer but not significantly more costly alternative series of commuting decisions I could make, I should take one of these alternatives.

This principle seems plausible for our case. It implies that you should not cycle every day for a year, but does not rule out cycling on at least some days. Rather, you should cycle on few enough occasions such that, over the course of any one-year period, you take only a negligible risk. The principle does not rule out continuously using methods of commute that only result in non-negligible risks over stretches of time longer than a year (e.g. cycling once a week). This is what avoids the problem of implausibility at the global scope.

I think the first response is sensible if our sole purpose is to arrive at correct moral principles or principles of rationality, but not necessarily to find principles that are effectively action-guiding. The first response yields more general principles than the second; and it is independently plausible that precaution should not come at just *any* cost. On this view, precautionary principles allow us to disregard the potential upsides of a risky activity only within certain limits, thus ruling out what we might consider fanatical levels of precaution. When coming up with the right precautionary principles, we thus need to think systematically about what maximum cost precaution should come at.

However, I take the second response to the problem of scope proposed here to be superior for the purpose of effective action-guidance, for two reasons. First, on the first response, precautionary principles would only effectively guide choice if agents actually apply the principle at all scopes. Agents aiming to be guided by a precautionary principle in action would need to consider all of the activities – incremental, extended, or global – that they are, or are considering being engaged in, and check not only whether these involve risks that pass the harm and likelihood thresholds of a precautionary principle, but also whether taking such risks is necessary for some other important enough goal. There is thus a lot for agents to consider, a lot more room for disagreement, and for errors to be made if agents do not actively take a long-term perspective. Secondly, introducing another vague threshold in the formulation of a precautionary principle adds further to the problem of execution discussed in the next section.

The re-formulation in the second response considered here, by being explicit about scope, provides more straightforward and specific action-guidance. This is especially fitting in the policy arena, where precautionary principles are usually put forward for a specific policy or decision context, and are meant to be applied fairly directly to a particular policy problem at hand. Either way, however, the problem of scope has implications for how precautionary principles should be formulated. They must either include a clause

that rules out implausibility at the global scope, or they should make scope explicit. Neither is commonly done in the literature on precautionary principles. And either way, precautionary principles end up being diachronic principles: In the second case explicitly so, as here precautionary principles explicitly constrain temporally extended courses of action. And in the first case, because agents are expected to apply the principle to all scopes of activity, including extended ones. In the face of risks that accumulate over time, precautionary principles can only guard against excessive risk-taking when they are formulated and/or understood as diachronic principles.

5 The Problem of Execution

Precautionary principles are meant to guard against especially serious risks. As decision-making tools, they are meant to help agents and policy-makers overcome temptations to postpone precautionary action or ignore risks, in particular those that are especially hard to quantify. What we have seen so far is that the kinds of risks precautionary principles are meant to guard against often only accumulate as the result of many incremental actions over time, where no individual incremental action considered in isolation creates serious enough risks for the relevant precautionary principle to constrain the agent. For precautionary principles to still effectively guard against the cumulative risk, they must be understood as diachronic principles that may constrain series of choices even if they don't constrain individual choices in isolation. In the last section we saw that in order to do so, some additional structure is needed on top of the standard structure of precautionary principles: Either the scope of the target extended activity must be made explicit, or precautionary principles should be applied at all scopes of extended activity, with additional caveats introduced to avoid implausibility at the global scope.

I here want to raise two challenges for such diachronic precautionary principles being effectively action-guiding in cumulative potential harm and cumulative likelihood cases. The first arises due to the vagueness of thresholds of standard precautionary principles. The second is specific to the case of transient cumulative likelihood cases. The problem here is that agents will fail to abide by the precautionary principle if they don't take into account bygone risk, which is an unintuitive thing to do.

Incremental activities that cumulatively bring about a vague harm for certain, or undermine a vague end for certain have been argued to be especially difficult to keep in check, leading to procrastination or inability to prevent the harm or achieve the end (see, e.g. Andreou (2006), or Tenenbaum and Raffman's (2012) discussion of Quinn's Self-Torturer Problem). The problem in such cases is that no incremental activity on its own seems to bring about harm or affect the agent's ability to achieve her end. If the activity

moreover brings with it individually tangible benefits, an agent may always reason that it is better to perform the action, in which case she will over time bring about harm or fail to achieve her end.

Precautionary principles with vague thresholds are subject to a similar problem in cumulative potential harm and cumulative likelihood cases just in case the recommended precaution also needs to be implemented incrementally – as is the case when precaution takes the form of omission, reduction, or altered performance of the incremental activity.²² In these cases, each incremental activity does not make a difference to whether the agent abides by the restriction of the precautionary principle,²³ and is otherwise very attractive. One additional missed practice session does not make a difference to whether you manage to avoid a substantial risk of failing the piano exam. But you do enjoy playing video games for an hour. And so each time you consider playing the video game instead of practicing, it might seem that you should play the video game – *even though* you accept the normative authority of the diachronic precautionary principle. But if you always reason like this, you will certainly fail to abide by the diachronic precautionary principle. Similarly, even if a policy-maker accepts the normative authority of a diachronic precautionary principle aiming to address the risks of catastrophic climate change, she might reason that no incremental policy decision and no day of delay ever makes a difference to whether she abides by the precautionary principle.

To abide by the restriction of diachronic precautionary principles with vague thresholds, agents will have to arbitrarily pick amongst several permissible ways to implement it. In our examples, this means arbitrarily picking some incremental activities not to perform. In order to abide by the precautionary principles discussed above, you need to refuse to invest in a startup, practice piano, and take alternative transport enough of the time to keep risks below the threshold, even though each individual incremental activity makes no difference to whether you abide by the principle. This is hard to implement, and arguably requires planning and commitment. As Andreou (2007) argues, in such circumstances, agents do best by forming an implementation intention that specifies how many times and on what occasions they should refuse to perform the incremental activity. But even once you have formed a plan, it remains true that performing just one more incremental activity than planned won't make you cross the threshold of the relevant precautionary principle.

²²The problem I point to here does not arise for precautionary principles where the recommended precaution is some separate measure that should be taken once risks resulting from our actions have passed the relevant thresholds, e.g. issuing warnings about drinking tap water once the water is polluted enough to pose health risks. In these cases, vague thresholds don't create a temptation for indefinite delay, but only unclarity about precisely when the precaution should be taken. However, as proponents of precautionary principles tend to emphasise prevention and mitigation of risks over adaptation to and protection from potential harms, such less problematic cases can be expected to be rarer.

²³Or, for the epistemicist, that it makes such a difference is highly unlikely in the borderline region, and for the supervaluationist, whether it does so is indeterminate in the borderline region (see Appendix). The same qualifications apply in the following.

And so there is a temptation to abandon your plan. Hence, commitment is also needed, which could be achieved with various external commitment devices, such as asking your flat mate to lock your console away. Moreover, as argued in Andreou (2007), there is a second-order procrastination problem relating to the initial forming of a plan and setting up of commitment mechanisms. All of these obstacles to effective implementation are compounded in the policy context by the difficulty to reach agreement.

What this shows is that in cumulative potential harm and cumulative likelihood cases, diachronic precautionary principles may give us the intuitively right answer regarding what individual agents or policy-makers should do (e.g. they should fail to perform the incremental activity enough of the time); but the vagueness of their thresholds invites procrastination or failure to guard against the relevant harms nevertheless. This is an obstacle for precautionary principles serving as *effective* action-guiding principles. Even agents who accept the normative authority of a precautionary principle may find it hard to go through with its recommendations. They arguably will need other decision-making tools, such as implementation intentions and commitment devices, to effectively guard against the cumulative risk.

There is an additional obstacle to implementation in the case of transient cumulative likelihood cases. And that is that unless agents take bygone risks into account, agents will likely never feel pressure not to perform an incremental activity in such cases. Take the cycling case, and suppose our precautionary principle rules out cycling every day in any one-year period. There is not much pressure to refrain from cycling on the very first day of the first one-year period. After all, there is still lots of opportunity to refrain from cycling to stay below the risk threshold. On the next day, you know you did not have an accident yesterday. It is thus natural to no longer take yesterday's risk into account, and to either (i) no longer take into account one-year series of choices whose risk has already partially resolved, or (ii) consider, from your ex post perspective, yesterday to be a no-risk day. Either way, there is again no pressure to refrain from cycling. It is still as if you were considering to take the first risk. But if you continue reasoning this way, you will always cycle, and the precautionary principle has not constrained your choices at all. The same reasoning could extend to cases of transient risk imposition on others, for instance when trying to keep the risk of spreading a dangerous virus below a certain acceptable threshold over extended periods of time. And policy-makers may also be subject to it. For instance, a policy-maker may repeatedly delay phasing out the use of a dangerous technology insofar as the risks it poses are transient. Suppose an initial plan is to phase out the technology over a ten-year period. If there is no major accident in the first year of this ten-year period, it might seem like there is no reason not to restart the clock.

I find this kind of case genuinely puzzling. On the one hand, this reasoning isn't obviously mistaken. If it is not, precautionary principles may simply be inapplicable

to transient cumulative likelihood cases. On the other hand, *ex ante*, the inability to constrain transiently risky activities does seem problematic. In any case, the attraction of reasoning ignoring bygone risk, and the unnaturalness of taking it into account at least form another, and distinct, obstacle to implementation of precautionary principles. As before, forming an implementation intention and being committed to its implementation (whether with the use of external commitment devices or not) may help overcome this obstacle. Precautionary principles then again have only limited effectiveness as action-guiding principles on their own, and their implementation needs to be supported by other decision-making tools.

6 Conclusion

When risks are hard to quantify or precise quantification is hard to agree on, traditional forms of policy evaluation and rational choice cannot straightforwardly be applied. There is then a risk of either ignoring such risks or putting off taking precautionary action. The hope of proponents of precautionary principles is that they can be effective action-guiding principles that help agents address such risks. To play this role well, precautionary principles not only need to make plausible recommendations, they also need to provide useful action-guidance and effectively constrain choice.

This paper presented an important obstacle for precautionary principles serving their function well. Risks that are sufficiently likely and sufficiently harmful to trigger application of a precautionary principle often accumulate over time as the consequence of many incremental activities none of which creates significant risks when considered in isolation. Consequently, if we want precautionary principles to help us guard against those risks, they must be able to govern an agent's decision-making over time. To do so without making implausible recommendations, they must be understood to be diachronic principles which have some additional structure to how they are usually formulated: Either they must make explicit the scope of the activity they are meant to be applied to (which provides the more straightforward action-guidance), or they must introduce a further condition that rules out implausibility when the principle is applied at a global scope.

Treating precautionary principles as diachronic principles in this way makes it the case that they can recommend precaution in the face of cumulative risks. This solves the normative problem posed by cumulative risk cases, but it does not solve what I have called the problem of execution. Are such diachronic precautionary principles effective action-guiding principles? I raised two challenges for the effectiveness of diachronic precautionary principles that arise in cumulative risk cases. Both the vagueness of thresholds of harm and likelihood and the fact that it is natural to ignore bygone risks create obstacles for the

implementation of diachronic precautionary principles. And so, while diachronic precautionary principles might serve as plausible normative principles in cumulative risk cases, and ones that might garner more widespread support than any particular risk-cost-benefit analysis, they are unlikely, on their own, to be effective decision-making tools to guard against (policy) procrastination, inaction or recklessness. They need to be complemented with implementation intentions and commitment devices. If we want to bring about more precautionary policies, or foster greater precaution in our individual lives against temptations to the contrary, we are well advised not to place all our focus merely on formulating, promoting and accepting precautionary principles. More than precautionary principles are needed for a sense of urgency to be translated into action.

Appendix: Theories of Vagueness and the Application of Precautionary Principles to Incremental Activities

Can the major theories of vagueness accommodate the intuitively plausible tolerance assumptions in cumulative likelihood and cumulative potential harm cases? That is, can they accommodate the assumption that no sufficiently finely individuated incremental activity can make the agent in such cases cross the harm or likelihood thresholds specified in the antecedent of the relevant precautionary principle? And if they can't, do they imply that precautionary principles restrict incremental activities after all?

Contextualists about vagueness, such as Raffman (1994) can in fact accommodate tolerance assumptions in the form that they matter for our analysis. According to contextualists, subtle context shifts will make it the case that, while there are sharp thresholds, these never lie 'where we are looking', that is, in an area we are actively considering. And so one kind of tolerance assumption does hold true: No incremental activity *she is actively considering* ever makes an agent cross the vague harm and likelihood threshold of a precautionary principle. But this kind of tolerance assumption is all we need for the judgement that, when incremental activities are considered in isolation, the precautionary principle will never restrict an agent: When an agent is actively considering only whether to make the next investment or to practise the next hour, it is in fact true that this will not make the difference to whether there is a plausible chance of financial ruin or a substantial risk of failure, and so the antecedent of the precautionary principle turns out false.

Epistemicists about vagueness, such as Williamson (1994), on the other hand, do accept that there is some incremental activity that takes an agent from, e.g. a non-substantial to a substantial chance of failure, even as the agent is actively considering that incremental activity. Epistemicists hold that thresholds can only be vague in the sense that it is impossible for an agent to know which incremental activity does so. Borderline cases,

on this account of vagueness, are simply cases of impenetrable uncertainty. Epistemicism thus introduces uncertainty about whether the antecedent of a precautionary principle is true for any incremental activity, and thus about whether a restriction applies to the agent. Indeed, when choices are individuated very finely, as they are in our examples, epistemicism implies that it would be subjectively very unlikely for any individual incremental activity to make an agent cross a vague threshold. According to epistemicism, agents can say with certainty that one of an extended series of incremental activities will make them cross a vague threshold, making the precautionary principle bite for certain when an extended enough series of choices is considered. But any individual choice is unlikely to make the antecedent of the principle true.

Whether precautionary principles constrain incremental activities, according to epistemicism, thus depends on how we think agents should act when there is only a small chance a deontological restriction applies. On an extremely risk averse construal, whenever there is any chance the antecedent of the precautionary principle is true, the agent should assume the restriction applies. On any more liberal construal, epistemicism is compatible with the intuitive analysis of the cases we started out with, at least if the incremental activities are individuated finely enough (and thus the chance any individual choice will take the agent over the threshold is small enough): The precautionary principle does not rule out incremental activities individually, while it may constrain series of the same choices when applied to extended courses of action. And even under the most risk averse construal, where the agent assumes the restriction applies whenever there is any chance of the antecedent being true, the recommendation of the precautionary principle in the borderline region is unclear, due to the widely accepted higher-order vagueness concerning when the borderline region of the application of a vague predicate begins. For the epistemicist, this amounts to the question of which is the first incremental activity for which there is some chance it is the sharp threshold. When there is higher-order vagueness, this question, for the epistemicist, is itself one that is subject to uncertainty. Given such higher orders of uncertainty, it is a complicated matter for an agent to work out whether the restriction of a precautionary principle applies to her or not when considering an incremental activity. The answer, in theory, will depend on a theory of choice we simply do not have yet, which tells us how to act when there is higher-order uncertainty about whether a deontological restriction applies to us. And in practice, on the epistemicist account of vagueness, the precautionary principle does not seem to have any useful action-guiding role to play when applied at the level of individual choices. Given the application of the precautionary principle now appears to involve making judgements under deep uncertainty, the precautionary principle at least no longer has a claim to being less subject to paralysis in the face of deep uncertainty than expected utility theory or risk-cost-benefit analysis in the original first-order choice context.

A third prominent theory of vagueness, namely supervaluationism, as defended by, e.g.

Fine (1975), characterises borderline cases in such a way that for them, it is indeterminate whether the vague predicate applies or not. The application of precautionary principles to incremental activities in the borderline region is complicated on such accounts, and our analysis will be parallel to the case of epistemicism. According to supervenience, there are many admissible precisifications of a vague predicate in the object language, and on each precisification, it is either true or false that the vague predicate applies. A sentence is supertrue if and only if it is true on all admissible precisifications. And its truth is indefinite if and only if it turns out true on some and false on others. Now take some incremental activity in the borderline region. There is likely going to be one admissible precisification under which it is true that it takes you, e.g., from a chance of non-financial ruin to a chance of financial ruin. But there are going to be many others on which this is false. So the truth of the antecedent of the precautionary principle will be indeterminate. What does the precautionary principle recommend in such a case? If we understand the precautionary principle in the object language, it is going to be indeterminate if the agent is constrained by the principle. Under most precisifications, the agent is unconstrained by it, but under at least one, she is.²⁴ It is unclear how agents should act when it is indeterminate whether some deontological restriction applies, and I am not aware of any account of choice under this kind of indeterminacy. As with epistemicism, we at best get the result that the precautionary principle does not give useful action-guidance when applied to incremental activities. And, unless we take a very conservative approach to choice under indeterminacy, this account, too, is compatible with what I take to be the intuitive analysis of these cases: The precautionary principle does not constrain agents when applied individually to sufficiently small incremental activities, while it does constrain a sufficiently long series of those activities when applied to the series.

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²⁴We could, at this point, formulate the precautionary principle in the metalanguage. Two options here are: ‘If it is not superfalse that some choice has a plausible chance of leading to financial ruin, don’t do it’; and ‘if it’s supertrue that some choice has a plausible chance of leading to financial ruin, don’t do it.’ But these principles are themselves only going to give definite recommendations when there is no higher-order vagueness. And it is generally accepted that the borders of borderline regions of vague predicates are themselves vague.

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