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OF CLIMATE CHANGE, QUANTUM PHYSICS AND CAUSATION: IS IT TIME FOR A PROBABILISTIC APPROACH TO CAUSATION IN TORT LAW?

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Abstract

The requirement that a plaintiff prove causation has hampered the success of tort-based claims against corporate greenhouse gas emitters. The need for an alternative approach to causation is clear. In recent years, courts and academics have engaged with the task of finding viable alternatives to the dominant "but-for" test for causation. This paper adds to that endeavour by proposing a new line of enquiry, grounded in approaches to causation that have emerged in scientific disciplines. It argues that the demise of deterministic theories of causation in science, and the rise of indeterministic and probabilistic alternatives, could be of interest to lawyers seeking a new approach to causation in law that is better tailored to the challenges of climate change. The paper contends that courts' rigid application of the but-for test is rooted in a fallacious, Newtonian assumption that all things have a determinate cause. It advocates instead for a probabilistic approach, drawing on Fairchild v Glenhaven Funeral Services Ltd *as evidence of its feasibility. Such an approach, it is argued, creates a real prospect of success for climate change litigants.*

Keywords: *"Climate change", "Causation", "Tort law", "Law and science", "Probabilistic causation".*

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I Introduction

Climate change litigation is on the rise.[1] According to a United Nations Environment Programme report, the number of climate change actions filed as of 2020 had more than doubled since 2017, with at least 1,550 such cases filed across 38 countries in 2020.[2] Of the various causes of action being deployed by climate change plaintiffs,[3] one trend has been the use of tort law to attempt to hold corporate emitters liable for harms suffered as a result of the changing climate.[4] Despite the popularity of such claims, plaintiffs continue to falter at a common hurdle: causation.[5]

With the multiplicity of emitters worldwide, climate change plaintiffs have so far struggled to prove the particularised link the law demands between their harm and a single defendant's emissions. Most critically, they have not been able to prove on the balance of probabilities that the defendant's activity was the 'but-for' cause of their harm. The result is unfortunate: a harm to which so many have contributed has become a harm for which "all of us and none of us [are] responsible".[6]

While climate change actions provide a convenient factual matrix to illuminate the restrictive nature of legal causation, it is not a new legal dilemma. The past half century has been a time of experimentation for judges and academics, marked by a number of attempts to develop alternatives to the law's prevailing but-for test that meet our contemporary needs. This paper seeks to contribute to this climate of experimentation by offering a new angle from which causation could be analysed, grounded in science.

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[1] United Nations Environment Programme *Global Climate Litigation Report: 2020 Status Review* (Nairobi, 2020) at 2.

[2] At 4.

[3] 'Climate change plaintiff' is used to refer to any person or body that has brought a climate change-related legal action. The category is vast, including those seeking relief for climate harms, asserting climate rights, and challenging domestic enforcement of international commitments: see generally United Nations Environment Programme, above n 1.

[4] At 22–23. Public actors have also been the target of tort actions: see generally *Sharma by her litigation representative Sister Marie Brigid Arthur v Minister for the Environment* [2021] FCA 560, (2021) 391 ALR 1 [*Sharma v Minister for the Environment*].

[5] Helen Winkelmann, Susan Glazebrook and Ellen France *Climate Change and the Law* (paper presented to the Asia Pacific Judicial Colloquium, Singapore, 28 May 2019) at [101]; and Saul Holt and Chris McGrath "Climate Change: Is the Common Law Up to the Task?" (2018) 24 Auckland U L Rev 10 at 13.

[6] Douglas A Kysar "What Climate Change Can Do About Tort Law" (2011) 41 Environmental Law 1 at 4.

Scientific understandings of causation have undergone an important paradigm shift over the last three centuries. From the deterministic model that prevailed under Newtonian physics, many philosophers of science have come to adopt a more indeterministic understanding of the world, precipitated by the quantum mechanics of the 20th century.[7] Accompanying this shift is a greater reliance on probabilities and, relatedly, probabilistic notions of causation.[8]

In this paper, I will trace the developments in understandings of causation in the philosophy of science and various scientific disciplines, and seek to apply these findings to develop a more sound understanding of causation in law. Furthermore, I will demonstrate how a more probabilistic notion of causation could aid the plaintiff in a climate change tort action.[9] Ultimately, it will be shown that science could indeed prove to be an illuminating line of enquiry that jurists should be more willing to pursue in their search for a more coherent approach to causation. Its potential must be realised now, as we enter a critical time in the planet's history.

II A War of Two Worlds: Climate Change and Causation

An emerging trend in the mounting body of climate change litigation is the use of tort law to sue corporate emitters for the harmful effects of climate change.[10] Although Winkelmann CJ, Glazebrook and France JJ have suggested extra-judicially that such claims are unlikely to "form the core of climate change litigation in future", predicting instead a resort to public law remedies,[11] tort claims have been, and continue to be, brought. Three examples can be given.

First, in *Native Village of Kivalina v ExxonMobil Corp*, the governing body of an Inupiat village in Alaska brought a claim in nuisance against twenty-four oil, energy and utility companies that they alleged were responsible for the erosion and destruction of the Kivalina coast through their contribution to global warming.[12] Second, in *Lliuya v RWE*

[7] See generally Lev Vaidman "Quantum Theory and Determinism" (2014) 1 Quantum Stud Math Found 5.

[8] See generally James H Fetzer "Probabilistic Metaphysics" in Ellery Ells and James H Fetzer (eds) *The Place of Probability in Science* (Springer, Dordrecht, 2010) 81; and Wesley C Salmon *Causality and Explanation* (Oxford University Press, New York, 1998).

[9] A 'probabilistic notion of causation' would define a 'cause' as a factor that raises the probability of its effect: Jon Williamson "Probabilistic Theories" in Helen Beebee, Christopher Hitchcock and Peter Menzies (eds) *The Oxford Handbook of Causation* (Oxford University Press, Oxford, 2009) 185 at 187.

[10] United Nations Environment Programme, above n 1, at 22–23.

[11] Winkelmann, Glazebrook and France, above n 5, at [109] and [134].

[12] *Native Village of Kivalina v ExxonMobil Corp* 696 F 3d 849 (9th Circ 2012).

AG, a Peruvian farmer filed claims for declaratory judgment and damages, alleging that the corporate defendant's emissions had contributed to the melting of nearby glaciers, in respect of which the plaintiff was forced to incur considerable mitigation expenses.[13] The defendants' emissions were characterised as a nuisance. Finally, New Zealand saw its first tort-based climate action in *Smith v Fonterra Co-Operative Group Ltd*, in which the plaintiff sued several corporate emitters, alleging that their emissions amounted to a public nuisance, negligence and breach of an inchoate duty.[14] While the actions in public nuisance and negligence were struck out, the question of an inchoate duty was allowed to proceed to trial.[15]

Critically, with the exception of one claim in the Federal Court of Australia,[16] no plaintiff has yet succeeded in convincing a court of the requisite causal link in a climate change tort action. Indeed, as this section will argue, legal notions of causation are entirely at odds with the factual features of a climate change claim sounding in tort.

A Legal Causation

The prevailing test for causation in tort law is the but-for test. A plaintiff must prove on the balance of probabilities that, were it not for the defendant's actions, they would not have suffered the relevant harm. The test is ultimately dyadic: its satisfaction relies upon a particularised, linear link being established between the specific defendant's actions and the specific plaintiff's harm.[17] The reason for this can be traced back to one of its most widely asserted aims: corrective justice.

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[13] *Lliuya v RWE AG* [2015] 2 O 285/15 Essen Regional Court (Germany), 15 December 2016; and see Climate Case Chart "*Luciano Lliuya v RWE AG*: Decision (unofficial translation)" (15 December 2016) < http://climatecasechart.com/climate-change-litigation/wp-content/uploads/sites/16/non-us-case-documents/2016/20161215_Case-No.-2-O-28515-Essen-Regional-Court_decision-1.pdf >.

[14] *Smith v Fonterra Co-Operative Group Ltd* [2020] NZHC 419, [2020] 2 NZLR 394 at [2].

[15] At [109].

[16] In *Sharma v Minister for the Environment*, a causal link was established in a very limited sense. The plaintiffs sought an *in quia timet* injunction to restrain the Minister for the Environment from granting consent for a coal mine extension. In finding that the Minister owed the plaintiffs a duty of care, Bromberg J considered that the CO_2 predicted to be emitted by the extension *could* foreseeably cause the plaintiffs harm in the future – a causal link of sorts. As a prospective inquiry, however, it differs significantly from that at issue in this paper. The Judge ultimately refused to grant the injunction sought, not wishing to pre-empt the Minister's decision: *Sharma v Minister for the Environment*, above n 4, at [247]–[257] and [508].

[17] Douglas A Kysar "The Public Life of Private Law: Tort Law as a Risk Regulation Mechanism" (2018) 9 European Journal of Risk Regulation 48 at 52.

Proponents of corrective justice assert that tort law operates in order to repair the imbalance that results when one party causes harm to another.[18] The private law is presented as "correlatively structured: the parties are connected solely as the doer and sufferer of the same injustice".[19] The "repair" that tort law mandates must therefore be addressed as a matter between the particular parties involved,[20] with causation acting as the "mechanism that links what this particular defendant has done to what this particular plaintiff has suffered".[21] Given the primacy of causation as this mechanism, corrective justice is "particularly resistant to reasoning that evades, loosens or depreciates this mechanism".[22] As Professor Douglas Kysar puts it, the law is reluctant to move beyond a "neat A-wrongfully-injures-B dyadic framework to recognise more complex and interrelated webs of causation and responsibility".[23]

B Application to Climate Change

Climate change claims are a textbook example of the "complex and interrelated webs of causation" to which Kysar refers.[24] They are therefore entirely incompatible with the law's current causal requirements. Three specific obstacles arise.

First, a climate change plaintiff will struggle to prove the particularised, linear link that the law demands between their harm and a defendant's activities. For example, in the first instance judgment in *Lliuya*, the Judge considered:[25]

> When innumerable major and minor emitters release greenhouse gases, which merge indistinguishably with each other, alter each other, and finally, through highly complex natural processes, induce a change in the climate, it is impossible to identify anything resembling a linear chain of causation from one particular source of emission to one particular damage.

Secondly, *everyone* is an emitter. A corporate defendant is therefore always going to be but one of over seven billion concurrent emitters. As was explained by Wylie J in *Smith v Fonterra*, this means the defendant's emissions are likely to be "miniscule in the context

[18] Gemma Turton *Evidential Uncertainty in Causation in Negligence* (Hart Publishing, Oxford, 2016) at 9.

[19] Ernest J Weinrib "Causal Uncertainty" (2016) 36 Oxford Journal of Legal Studies 135 at 137–138.

[20] Kysar, above n 17, at 56.

[21] Weinrib, above n 19, at 136.

[22] At 137–138.

[23] Kysar, above n 17, at 56.

[24] At 56.

[25] Climate Case Chart, above n 13, at 6–7; and see also *Lliuya v RWE AG*, above n 13.

of the global greenhouse gas emissions which are causing climate change".[26] As such, in most cases a plaintiff will not be able to prove, on the balance of probabilities, that but for the defendant's emissions, the harm would not have occurred. As Wylie J said of the defendants in *Smith v Fonterra*, "[e]ven if they stop emitting greenhouse gases, either immediately or by 2030, and/or stop supplying products from which greenhouse gases are emitted, the science … suggests that it is likely that the damage will nevertheless eventuate", brought about by the multiplicity of other emitters who will still be emitting unrestrained.[27]

Thirdly, it will be difficult for a climate change plaintiff to show that their harm was caused by climate change at all. Given many of the consequences often attributed to climate change either have a non-trivial background rate of occurrence or are subject to natural fluctuations,[28] a plaintiff will struggle to prove that, in the absence of climate change, the harm would not have been produced by a naturally occurring phenomenon.

To succeed, climate change plaintiffs need to develop a different approach to causation.

C A Climate of Experimentation

Climate change actions are not the first to lack compatibility with the but-for test. The law's desire for a linear, determinate chain of causation, for example, is equally hard to reconcile with areas like liability for emotional harm,[29] and the complex field of torts known as 'toxic torts'.[30] As a result of lawyers' growing awareness of the inadequacies of the but-for test, the last half century has seen judges and academics alike experimenting with alternative approaches. Three examples can be given.

The first, archetypal example stems from the series of mesothelioma-related claims in the United Kingdom, commencing with the House of Lords' opinion in *Fairchild v Glenhaven*

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[26] *Smith v Fonterra*, above n 14, at [82].

[27] At [82].

[28] Kysar, above n 6, at 31; David A Grossman "Warming Up to a Not-So Radical Idea: Tort-Based Climate Litigation" (2003) 28 Colum J Envtl L 1 at 24; and Eduardo M Peñalver "Acts of God or Toxic Torts? Applying Tort Principles to the Problem of Climate Change" (1998) 38 Nat Resources J 563 at 581–582.

[29] Minds do not operate via a straightforward, linear mechanism whereby input X leads to output Y.

[30] Examples include the DES litigation of the 1970s, tobacco litigation and asbestos-related claims: see generally *Sindell v Abbott Laboratories* 26 Cal 3d 588 (Cal 1980)*; Bullock v Philip Morris USA Inc* 198 Cal App 4th 543 (Cal 2011); and *Fairchild v Glenhaven Funeral Services Ltd* [2002] UKHL 22, [2003] 1 AC 32.

Funeral Services Ltd.[31] There, the plaintiffs had contracted mesothelioma after being exposed to asbestos by multiple employers.[32] Medical science was unable to identify, on the balance of probabilities, which of the employers had been the source of the fibre or fibres which had produced each plaintiff's malignant tumour.[33] As such, it could not be said that the plaintiffs would not have contracted the disease, but for any of the defendants' tortious exposures.[34] However, this was not fatal to the claim. Rather, the House of Lords decided to depart from the usual standard of but-for causation to hold that it would be sufficient if the plaintiff could prove that each defendant had materially increased the risk of their suffering harm.[35]

Secondly, academics like Professor Jane Stapleton have been equally creative. Stapleton has written at length of the but-for test's tendency to exclude an important category of cases: those where the defendant's activity makes a positive contribution to the relevant causal mechanism but is neither necessary nor sufficient in itself to bring about the plaintiff's loss.[36] According to Stapleton, the law is still normatively concerned with such causes.[37] For example, she says, a defendant who, together with two others, negligently pushes a car over a cliff should still be considered a 'cause', even if his two companions could have done so without him, and even if his own contribution was insufficient to do so on its own.[38] This defendant, however, would not satisfy the but-for test. Stapleton has therefore devised an "extended but-for test", under which a factor can still be considered causal if it "resulted in some positive contribution to the relevant mechanism by which the phenomenon came about".[39]

Thirdly, Stapleton's writings appear to have been influential in a recent decision of the United Kingdom Supreme Court, *Financial Conduct Authority v Arch Insurance (UK)*

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[31] See generally *Fairchild v Glenhaven Funeral Services Ltd*, above n 30; *Barker v Corus (UK) Ltd* [2006] UKHL 20, [2006] 2 AC 572; and *Sienkiewicz v Greif (UK) Ltd* [2011] UKSC 10, [2011] 2 AC 229.

[32] *Fairchild v Glenhaven Funeral Services Ltd*, above n 30, at [3]–[5].

[33] At [7].

[34] At [2].

[35] At [42], [34], [47], [108] and [168].

[36] Jane Stapleton "Unnecessary Causes" (2013) 129 LQR 39 at 39; and Jane Stapleton "An 'Extended But-For Test' for the Causal Relation in the Law of Obligations" (2015) 35 Oxford Journal of Legal Studies 697 at 710.

[37] Stapleton "Unnecessary Causes", above n 36, at 44–45.

[38] At 43.

[39] At 39.

Ltd.[40] There, the Court had been asked to resolve a number of questions about the meaning and effect of insurance policy wordings in the context of COVID-19.[41] One central issue was whether business losses incurred as a result of Government response measures would have cover, requiring the Court to assess the degree of causal connection that would be necessary between a case of COVID-19 within the insured radius and the relevant business loss.[42] Similarly acknowledging the over-exclusivity of but-for causation, their Lordships resolved to depart from it.[43] Thus, they concluded that an insured peril, which in combination with many other uninsured events brought about a loss, could still be regarded as a cause, even if its occurrence was neither necessary nor sufficient to bring about the loss by itself.[44] That is, even if the loss would still have occurred in its absence.

With these departures in view, it becomes clear that we are in a climate of experimentation: the shortcomings of the 'but-for' test have been acknowledged, and jurists are seeking to devise an alternative. There is, however, one potential line of enquiry that is too often overlooked. As courts come to grapple with increasingly complex and technical factual scenarios, I propose that it is time to make use of what could be an edifying new lens: science. Having experienced its own evolution in understandings of causation, science has the potential both to illuminate the flaws in legal notions of causation, and to direct lawyers towards a more coherent alternative.

III Causation in Science and Law

During the last two centuries, scientific notions of causation have undergone an important paradigm shift.[45] From the prevailing determinism of Isaac Newton's day, a more indeterminate, probabilistic notion of causation has emerged.[46] Though catalysed by developments in physics, the shift is evident in various scientific disciplines, from chemistry to epidemiology.[47] The common feature of all such disciplines is the primacy of

[40] Their Lordships referred to Stapleton extensively in their reasoning: *Financial Conduct Authority v Arch Insurance (UK) Ltd* [2021] UKSC 1, [2021] AC 649 at [183]–[185].

[41] At [1].

[42] At [161].

[43] At [182]–[183].

[44] At [191].

[45] Fetzer, above n 8, at 81.

[46] At 81.

[47] See Mark Parascandola "Causes, Risks and Probabilities: Probabilistic Concepts of Causation in Chronic Disease Epidemiology" (2011) 53 Preventative Medicines 232 at 232–233.

probability and chance, rendering the traditionally mechanistic notion of causation unsuitable and inaccurate.[48]

While science has evolved, the law's conception of causation has remained rooted in the determinism of the 18th century.[49] The purpose of the following parts is therefore to assess whether the law could benefit from a similar evolution, and indeed what such an evolution could look like. First, however, it is instructive to trace the changes in science's narrative.[50] I will start by explaining the science underlying the shift, and how this has changed the epistemological framework in which causes are assessed. I will use the discipline of epidemiology to illustrate practically how such developments have led to a greater acceptance of probabilistic causation. Finally, I will illustrate how this approach could be used to inform legal causation.

A Science's Changing Narrative

1 Determinism and classical mechanics

Determinism has ancient roots. Around 440 BC, Leucippus stated, "Nothing occurs at random, but everything for a reason and by necessity."[51] In the philosophy of science, however, it was not until Newton coined his three laws of motion in the 17th century that causal determinism truly came to the fore.[52] Science came to know Newton's law of inertia, dictating that a body will remain at rest or moving at constant speed unless acted upon by an external force; his law of force and acceleration, under which the acceleration of an object is directly governed by the net force acting on it; and his law of reaction, understood to mean that every force has an equal and opposite reaction.[53] These laws effectively 'proved' what determinists had been arguing for years: that with sufficient information about the antecedent conditions of an event, we can predict with certainty what the outcome will be – that is, that the outcome of an event is predetermined by pre-existing causes.[54] Thus, the predominant view of causation at the time was entirely deterministic: particles

[48] At 232–233; and see Salmon, above n 8, at 271–273.

[49] Glen O Robinson "Probabilistic Causation and Compensation for Tortious Risk" (1985) 14 JLS 779 at 780–781; and Peñalver, above n 28, at 582–583.

[50] Fetzer, above n 8, at 81.

[51] Leucippus *Fragment 569, Aetius I.25.4* as cited in Vaidman, above n 7, at 6.

[52] Margaret G Farrell "*Daubert v Merrell Dow Pharmaceuticals, Inc:* Epistemiology and Legal Process" (1994) 15 Cardozo L Rev 2183 at 2189.

[53] Gregory A DiLisi *Classical Mechanics: Newton's Laws and Uniform Circular Motion* (Morgan & Claypool, San Rafael (CA), 2019) at 3-3, 3-11 and 3-15.

[54] Robert C Bishop "Determinism and Indeterminism" in Robert C Bishop (ed) *Encyclopedia of Philosophy* (2nd ed, Thomson Gale, 2006) 29 at 30.

collide with particles, and the outcome of this collision is governed by immutable physical laws.[55] Ultimately, an infinitely advanced science was capable of knowing the cause of any phenomenon.[56]

2 A quantum leap

In the 20th century, however, a critical turning point took place. With the advent of quantum mechanics, the scientific underpinning of determinism was removed. In its place, indeterminism and more probabilistic theories of causation emerged. Fetzer describes this "demise of deterministic theories and the rise of indeterministic theories" as "the most striking feature of the history of science since Newton".[57] Two examples can be given to illustrate this shift: Rutherford's decay law and Heisenberg's uncertainty principle.

In 1902, Ernest Rutherford and Frederick Soddy penned the radioactive decay law, a statistical law that describes the process whereby an atom of one element transforms into an atom of another element through the emission of an alpha particle or beta electron from its nucleus.[58] The law works at the level of an *ensemble* of atoms, giving the probability that a given ensemble will decay within a given time.[59] Critically, however, at the level of the individual atom, the law holds that decay is a spontaneous and random process: it cannot be known when an atom will decay.[60] Indeed, the very term 'spontaneous' means the decay is self-initiated; there is no external set of circumstances that one can identify as a 'cause', nor use to predict when decay will occur. Rather, it can only be approximated by the exponential decay curve of the ensemble.[61]

This finding was a direct challenge to the prevailing notion of determinism at the time.[62] Rutherford and Soddy's inability to penetrate beyond the level of the ensemble was not

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[55] Troyen A Brennan "Causal Chains and Statistical Links: The Role of Scientific Uncertainty in Hazardous-Substance Litigation" (1987–1988) 73 Cornell L Rev 469 at 478.

[56] See Pierre-Simon Laplace *A Philosophical Essay on Probabilities* (Frederick Wilson Truscott and Frederick Lincoln Emory (translators), John Wiley & Sons, London, 1902) at 4.

[57] Fetzer, above n 8, at 81.

[58] Friedel Weinert "Radioactive Decay Law (Rutherford-Soddy)" in Daniel Greenberger, Klaus Hentschel and Friedel Weinert (eds) *Compendium of Quantum Physics: Concepts, Experiments, History and Philosophy* (Springer, Berlin, 2009) 630 at 630.

[59] At 631.

[60] At 630.

[61] Brigitte Falkenburg and Friedel Weinert "Indeterminism and Determinism in Quantum Mechanics" in Daniel Greenberger, Klaus Hentschel and Friedel Weinert (eds) *Compendium of Quantum Physics: Concepts, Experiments, History and Philosophy* (Springer, Berlin, 2009) 307 at 308.

[62] Weinert, above n 58, at 631.

considered to be a product of scientific ignorance or instrumental imprecision (what I will call 'epistemic indeterminism'), but a result of a genuinely indeterministic process in nature (what I will call 'ontological indeterminism'), governed not by consistent physical laws but by chance.[63] Thus, scientists and philosophers came reluctantly to accept that not all processes are predetermined and predictable, contrary to the dominant position under classical mechanics.[64]

A parallel development can be gleaned from Heisenberg's uncertainty relations, which denote the impossibility of knowing both the position and momentum of a particle simultaneously.[65] To measure momentum, one must alter a particle's position. To measure position, one must alter a particle's momentum. As a result, both the antecedent conditions (or the cause) and the resulting conditions (or the effect) cannot be known.[66]

On the surface, this may seem like a kind of epistemic indeterminism: an ostensible indeterminacy brought about by the limitations of equipment, rather than ontological indeterminism. However, as Salmon has argued, this is a mischaracterisation:[67]

> The reference to knowledge, ignorance, or uncertainty is regrettable. It would be far better to stick with the word indeterminacy to reinforce the idea that we cannot know exact values for position and momentum because such exact values simply do not exist. In this way, one can more readily understand that the future behavior of a particle such as an electron is not just unpredictable but also indeterminate.

Much like for Rutherford and Soddy, this intrinsic indeterminacy meant that recourse to probability had to be made. In place of knowing the precise location of a particle, equations such as the Schrödinger equation had to be used instead to calculate the *probability* of finding a particle in a particular region.[68] One example of this is the atomic orbital. Though a non-chemist might assume that these are actual physical entities – tracks on which electrons whir around – they are in fact mere probability descriptions of where an electron

[63] At 631; and Salmon, above n 8, at 272–273.

[64] Weinert, above n 58, at 631.

[65] Salmon, above n 8, at 262.

[66] Falkenburg and Weinert, above n 61, at 308.

[67] Salmon, above n 8, at 262.

[68] At 271–273.

is *likely* to be found in the region surrounding a nucleus.[69] A common theme, therefore, seems to be the use of probability to fill the informational lacunae left by indeterminacy.

Thus, it becomes apparent that the rise of indeterminism in scientific theory has necessitated a more capacious understanding of causality than that under the determinism of pre-quantum years. No longer can it be assumed that all events are predetermined by a certain and discoverable cause. The next question we must therefore ask is: how has the rise of indeterminism in scientific theory affected how causation is established in practice? I propose to answer this question by using the discipline of epidemiology as a case study.

B Causation in Practice: Epidemiology

Epidemiology is the study of the occurrence and distribution of diseases within specified populations.[70] As a crucial part of an epidemiologist's work is the identification of causes (or, as they are often termed, 'determinants') of a given disease, causation is a concept of central importance.[71] Causation in epidemiology has undergone an interesting shift over the last century, from an early insistence that a cause be both "necessary and sufficient" for a disease's occurrence, to what appears to be a greater openness to 'probabilistic causation'.[72] Although acceptance of this latter approach is far from universal, there has been a mounting body of literature in its support since the 1950s.[73]

At the start of the 20th century, the ramifications of the developments in quantum science were being felt all across science. For some, the rise of indeterminism engendered the end of causality. Bohr, Heisenberg and Pauli all concluded that uncertainty relations proved the 'acausal' nature of quantum mechanical systems.[74] Mathematician Karl Pearson asserted that the category of "cause and effect" was an arcane "fetish".[75] However, this view was soon superseded by alternative theories of causation. Of particular interest to the discipline

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[69] Chemistry LibreTexts "3D Representation of Orbitals" (13 June, 2021) <https://chem.libretexts.org/@go/page/21733>.

[70] Miquel Porta *A Dictionary of Epidemiology* (6th ed, Oxford University Press, Oxford, 2014) at "Epidemiology".

[71] The term 'determinants' does not imply a deterministic approach; the term is in fact probabilistic, referring to a collective or individual risk factor that is causally related to a health condition: see Porta, above n 70, at "Determinant(s)".

[72] Parascandola, above n 47, at 233.

[73] At 233–234.

[74] Falkenburg and Weinert, above n 61, at 308.

[75] Karl Pearson *The Grammar of Science* (3rd ed, Adam and Charles Black, London, 1911) at vi.

of epidemiology was that of statistician Ronald Fisher, who, in proposing his indeterministic notion of causality, wrote:[76]

> … [C]ausation is none the less recognisable, and an action is just as much an effective cause of subsequent events, *if it influences their respective probabilities*, as if it predetermines some one of them to the exclusion of the others.

It was in reliance on Fisher's explication above that epidemiologist E Cuyler Hammond came to propose his probabilistic vision of causation.[77] Thus, during the marked expansion of epidemiological studies on the link between cigarette smoke and lung cancer in the 1950s, Hammond warned of the inadequacy of traditional concepts of necessary and sufficient cause for biology and medicine.[78] Instead, he proposed that any condition that increases the *probability* of a specified event could be considered a cause.[79] Accordingly, despite medical science's failed attempts to identify a "definite, final, and single … causal agent" of lung cancer, as was traditionally sought,[80] smoking could still be considered causative, due to its influence on the probability of developing the cancer.[81]

Similarly probabilistic definitions have appeared across the epidemiological literature.[82] Another source, for example, defines a "cause of cancer" as "a factor that increases the probability that cancer will develop in an individual".[83] Accounts of causation in post-war textbooks also started to accommodate more probabilistic, multifactorial approaches, with

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[76] RA Fisher "Indeterminism and Natural Selection" (1934) 1 Philosophy of Science 99 at 106 (emphasis added).

[77] Parascandola, above n 47, at 233.

[78] E Cuyler Hammond "Cause and Effect" in EL Wynder (ed) *The Biological Effects of Tobacco* (Little, Brown and Co, Boston, 1995) as cited in Parascandola, above n 47, at 233.

[79] Parascandola, above n 47, at 233.

[80] See J Yerushalmy and Carroll E Palmer "On the Methodology of Investigations of Etiologic Factors in Chronic Diseases" (1959) 10 Journal of Chronic Diseases 27 at 28–30.

[81] Parascandola, above n 47, at 233.

[82] See Mark Parascandola and DL Weed "Causation in Epidemiology" (2001) 55 J Epidemiol Community Health 905 at 907–908; and LR Karhausen "The Logic of Causation in Epidemiology" (1996) 24 Scand J Soc Med 8 at 9–12.

[83] L Tomatis and others *Cancer: Causes, Occurrence and Control. IARC Scientific Publication No 100* (International Agency for Research on Cancer, Lyon, 1990) as cited in Parascandola and Weed, above n 82, at 908, n 37.

MacMahon and Pugh introducing the idea of a "web" of causation to replace the deterministic focus on establishing a causal chain.[84]

While some epidemiologists still insist on a strictly deterministic approach to causation, whereby a 'cause' is limited to a single necessary and sufficient condition, such a viewpoint is now considered to be held by only a "small minority" of epidemiologists, dismissed by others as a "product of the lingering historical influence of scientific determinism".[85] Epidemiology is therefore one discipline for which the rise of indeterminism elsewhere in science has triggered a revision of causation. Though causation remains a controversial topic among epidemiologists, there is at least a discernible trend away from the deterministic requirement that a cause be necessary and sufficient for its effect, and towards a more probabilistic theory. What remains to be asked, therefore, is: could the law benefit from a similar evolution?

C Determinism in the Law

Unlike its counterpart in science, legal causation has remained rooted in a deterministic metaphysics, its primary vector being the stringent but-for test.[86] As explained in Part II, the inquiry that this test directs us to make is: 'Would the plaintiff's harm have occurred, absent the defendant's conduct?'. If the answer is yes, then the defendant's actions are not a cause of the plaintiff's harm. If the answer is no, then the defendant's actions are prima facie causative.

The problem, however, is that this assumes that causal laws connect causes to their effects in an invariant, rather than probabilistic, way: if one takes away a true cause, the effect will always disappear; and if the cause is in existence, the effect is always inevitable.[87] As Professor Eduardo Peñalver has explained, the test is inherently deterministic, predicated on a Newtonian view of the world in which it is assumed that "all events proceed, by necessity, as a result of the conjunction of 1) a preceding state of affairs and 2) a set of universal, exceptionless, and, at least in principle, discoverable laws of nature".[88] However,

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[84] Brian MacMahon and Thomas F Pugh *Epidemiology: Principles and Methods* (Little, Brown and Company, Boston, 1970) at 25 as cited in Parascandola, above n 47, at 233.

[85] Parascandola and Weed, above n 82, at 906.

[86] Glen O Robinson "Probabilistic Causation and Compensation for Tortious Risk" (1985) 14 JLS 779 at 780–781; and Peñalver, above n 28, at 582–583.

[87] Steve C Gold "When Certainty Dissolves into Probability: A Legal Vision of Toxic Causation for the Post-Genomic Age" (2013) 70 Wash & Lee L Review 237 at 243.

[88] Peñalver, above n 28, at 580.

as has been illustrated above, the deterministic assumptions on which this is based are not always an accurate description of reality.

It might be asked why law and science have diverged in this way. One compelling answer is that jurists have been biased by the macro world in which they have traditionally operated.[89] As philosopher John Dupre has argued, there are numerous instances in our world where ontologically indeterministic processes can be convincingly approximated as deterministic processes when considered from afar. In other words, "macro-determinism" is often accompanied by an underlying "micro-indeterminism".[90] For example, macroscopic chemical reactions appear to be governed by strict laws of thermodynamics and stable equilibria, but are in fact dictated by the statistical mechanics of vast numbers of molecules, which operate stochastically at the level of the individual.[91] Even selective processes in evolution can seem deterministic when viewed in large populations, but are anything but deterministic when applied to the individual, whose traits are determined by chance.[92]

Tort law has traditionally operated in a macro world. Wright, for example, refers to the "bash/crash/slash" physical trauma situations that once dominated tort litigation,[93] and Kysar to tort law's "classic A-hits-B scenario".[94] In such cases, the causal chain is directly observed, and a number of satisfactory assumptions can be made as to its mechanism.[95] As the law need not concern itself with what is happening on a microscopic level, a deterministic test is adequate.[96] However, as tort law has come to grapple with more complex scenarios, in which the decisive process occurs at a level that is "unobserved and unobservable as it occurs, and inscrutable afterward",[97] this deterministic approximation is no longer sufficient.[98]

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[89] At 583.

[90] John Dupre *The Disorder of Things* (Harvard University Press, Cambridge (Mass), 1993) at 189.

[91] At 189.

[92] At 189.

[93] Richard Wright "Proving Causation: Probability versus Belief" in Richard Golberg (ed) *Perspectives on Causation* (Hart Publishing, Oxford, 2011) 195 at 205.

[94] Kysar, above n 17, at 53.

[95] Wright, above n 93, at 205.

[96] Peñalver, above n 28, at 583–584.

[97] Gold, above n 87, at 244.

[98] Peñalver, above n 28, at 590.

In Part II of this paper, I canvassed some alternatives to the but-for test that have been proposed by various academics and courts. In particular, a number of accounts have acknowledged the under-inclusivity of the but-for test, and have attempted to propose a more expansive alternative to account for situations where a factor bears a distinct causal relation to the plaintiff's loss, but was neither necessary nor sufficient to bring about that loss by itself.[99] Such accounts are some of the most significant revisions of causation the law has so far seen. However, when viewed from science's perspective, it becomes clear that they are still rooted in determinism, and are therefore inadequate.

Professor Gold has illustrated this point by reference to a well-known hypothetical, deployed with only slight variations by Stapleton, the Court in *Arch Insurance* and the American Law Institute's *Restatement (Third) of Torts*.[100] The hypothetical posits three actors (A, B and C), all of whom negligently lean on a car. Collectively, their combined forces push the car over the cliff. Each actor's individual contribution would have been insufficient to do so, but two actors' contributions would have been sufficient. Thus, no single actor is either a sufficient or necessary cause of the harm. Under the revised models referred to above, although A, B and C do not satisfy the but-for test, they can still each be considered a cause of the harm. However, as Gold has stressed, this still relies on an implicitly assumed mechanistic model of causation:[101]

> Simple Newtonian physics describes the situation: we can compute the force required to overcome the car's inertia and the static friction of its tires on the parking surface. If we could reconstruct the accident, we might find that 300 pounds of force were required to move the car and that [A, B and C] each provided 200 pounds. This knowledge, at least in qualitative terms, is implicit in the illustration's assumptions.

What, then, if the situation were not described by Newtonian physics, but by quantum mechanics? Thus, the hypothetical instead takes place on a cliff ringed with cars, and A, B and C charge around blindfolded. They are also joined by undetectable pockets of energy (Gold refers to these as 'sprites'), which impart momentum to any object they strike:[102]

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[99] See Stapleton "Unnecessary Causes", above n 36, at 39; and *Financial Conduct Authority v Arch Insurance (UK) Ltd*, above n 40, at [182]–[183].

[100] Gold, above n 87, at 282–284; see Stapleton "Unnecessary Causes", above n 36, at 43; *Financial Conduct Authority v Arch Insurance (UK) Ltd*, above n 40, at [184]; and American Law Institute *Restatement (Third) of Torts: Liability for Physical and Emotional Harm* (2010) as cited in Steve Gold, above n 87, at 282, n 186.

[101] Gold, above n 87, at 283.

[102] At 283.

> Sometimes [A, B and C] hit a car, and sometimes the impact is powerful enough to tip the car down the hill. But this is a quantum world: if we know what they hit, we cannot tell how hard they hit it. And we can't detect the sprite strikes at all. Every once in a while, a car rolls down the hill. But the most science can tell us – if we can say whether [A, B, C] or any combination of the three hit the car at some point before its descent – is the probability that they hit the car hard enough to make it move.

As this example illustrates, no deterministic test for causation will suffice when applied to indeterministic facts. The Newtonian assumptions underlying most legal tests are simply not valid in this indeterministic reality. It would seem, therefore, that a common theme plagues even the most promising modern alternatives to but-for causation: an assumption that science is wholly deterministic.

It is important to note that it is not my intention to argue that all of science is indeterministic. Indeed, it remains a point of much contention among scientists whether various processes are ontologically indeterminate (in the sense of having a bona fide indeterministic mechanism), or merely epistemologically indeterminate (in the sense that they only appear indeterminate because science lacks a full understanding of its mechanism).[103] Rather, I argue that for the law's purposes it should not matter whether a process is truly indeterministic, or whether it really has a determinate cause that current (or even future) science is simply incapable of knowing.[104] In either case, the critical point is that in its insistence on a deterministic causal model, the law is asking us to prove what it is impossible to prove.[105]

What, then, does science offer as an alternative? As has been emphasised throughout, a common motif all throughout science is the role of probability in filling the lacunae left by indeterminacy. I argue, therefore, that the approach most consistent with the growing role of indeterminism in science would be to adopt a probabilistic notion of causation. As Steel has stated, in so far as we are concerned with an indeterministic process, "we must talk in terms of probability".[106]

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[103] See Parascandola, above n 47, at 233.

[104] See Gold, above n 87, at 280–281.

[105] At 280–281.

[106] Sandy Steel *Proof of Causation in Tort Law* (Cambridge University Press, Cambridge, 2015) at 9.

IV Probabilistic Causation

A probabilistic test for causation defines a cause as any factor that increases the probability of its effect.[107] In a legal context, this means that a defendant's conduct would be considered a cause of the plaintiff's harm if it increased the risk of that harm being suffered.[108] Such an approach would remove the need to trace a linear but-for connection between a defendant's conduct and a plaintiff's harm in cases where such an exercise is impossible, whether due to an intrinsically indeterministic process or mere scientific uncertainty.

One might, at this point, wonder whether this is really so novel a suggestion. Indeed, the answer is no: it is an approach that we have in fact seen before in the House of Lords' opinion in *Fairchild v Glenhaven Funeral Services Ltd*. Controversial as this decision may be, I argue that it is at least a promising indication that judges may be open to a probabilistic approach in the future, albeit with some necessary qualifications.

A Fairchild *Revisited*

As explained in Part II, *Fairchild* was a case in which the limits of medical science meant that the plaintiffs were unable to prove on the balance of probabilities which of the defendants had caused them to contract mesothelioma.[109] Acknowledging this "rock of uncertainty",[110] their Lordships resolved to adopt an alternative approach to but-for causation, holding that it would be sufficient to prove that the defendant had *materially increased the plaintiff's risk* of contracting the disease.[111] Applied to the facts of each case, all plaintiffs were able to prove the necessary causal link on the balance of probabilities.[112]

In their reliance on ideas of risk, chance and probability, their Lordships adopted an overtly probabilistic approach to causation.[113] All members of the Court, bar one, saw themselves as adopting a different standard of causation to the law's usual but-for test, variously writing of "var[ying]", "relax[ing]" and "departing from" the traditional threshold.[114] Only

[107] Parascandola, above n 47, at 233; and Williamson, above n 9, at 187.

[108] See Gold, above n 87, at 281–282; and Ignacio N Cofone "The Limits of Probabilistic Causality in Law" (2015) 15 Global Jurist 29 at 32.

[109] *Fairchild v Glenhaven Funeral Services Ltd*, above n 30, at [3]-[7].

[110] At [7].

[111] At [42], [34], [47], [108] and [168].

[112] At [168].

[113] Chris Miller "Causation in Personal Injury Law: The Case for a Probabilistic Approach" (2014) 33 Topoi 385 at 385–387.

[114] *Fairchild v Glenhaven Funeral Services Ltd*, above n 30, at [9], [41] and [56].

Lord Hutton was of the view that the "material increase in the risk" test was merely a tool of inference, allowing the Court to infer that but-for causation had been established.[115] The other four members seemed content to accept an increase in probability as sufficient causation itself.

1 Addressing criticisms

However, *Fairchild* is not without its critics. When cause to consider the House of Lords' approach arose in the New Zealand Court of Appeal,[116] Glazebrook J noted its "uncertain scope and the absence of any overarching principle" in the novel test.[117] Even Lord Hoffmann, who was one of the Judges in *Fairchild*, has expressed his regret extra-judicially at the decision's ostensible lack of principle.[118]

Indeed, in the way that their Lordships justified the test, there may well have been a lack of discernible principle. Lord Hoffmann, for example, has admitted that the reasoning in *Fairchild* stemmed from an instrumentalist desire for justice, writing:[119]

> The reasoning in *Fairchild* was simply that we thought it very unfair that an employer should be able to escape any liability for mesothelioma suffered by a worker whom he had negligently exposed to asbestos simply because the worker had also been (negligently or otherwise) exposed to asbestos by someone else.

This does not mean the approach itself is wrong. Rather, I propose that their Lordships were moving in the right direction when they acknowledged the need for an alternative test where a so-called "rock of uncertainty" exists. What the decision lacked, however, was an acknowledgement that recourse to probability in cases of such uncertainty is justified by the fallacy of the assumption that all things have a determinate cause. Thus, the House of Lords' approach can in fact be rationalised by reference to the inappropriateness of a deterministic test in what is – at least in part – an indeterministic world.

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[115] At [109].

[116] See *Accident Compensation Corporation v Ambros* [2007] NZCA 304, [2008] 1 NZLR 340 at [33].

[117] At [35].

[118] Lord Hoffmann "*Fairchild* and After" in Andrew Burrows, David Johnston and Reinhard Zimmermann (eds) *Judge and Jurist* (Oxford University Press, Oxford, 2013) 63 at 65.

[119] At 64.

Furthermore, while the House of Lords' approach has been approved in subsequent mesothelioma cases,[120] courts have been reluctant to apply it to cases outside that factual realm, characterising the approach as an "exceptional rule",[121] or "narrow exception".[122] In principle, however, there is no reason the rule should be so confined; the "rock of uncertainty" by which it was justified is not something unique to asbestos claims. As Lord Brown noted in *Sienkiewicz v Greif (UK) Ltd*, courts are "faced with comparable rocks of uncertainty in a wide variety of other situations too".[123]

Thus, attempts at confinement aside, *Fairchild* is at the very least a promising illustration that a probabilistic approach has been applied by a higher court before. Furthermore, the principle it has been claimed to lack can, I argue, be found in science.

2 Thresholds and boundaries

There is, however, one notable difference between the basic definition of probabilistic causation offered by science, and the test adopted in *Fairchild.* Namely, this is the qualification in *Fairchild* that a defendant must have "materially" or "substantially" increased the plaintiff's risk of suffering harm.[124] This is not a qualification that I propose to challenge. Indeed, it is a normative addition that can be justified by reference to the disparate aims of science and law. Science, on the one hand, is a discipline that seeks to describe the world around us with as much detail as it can; even risk factors that do not reach a threshold of materiality may therefore be of interest.[125] On the other hand, law has a prescriptive and "predominantly normative orientation", seeking to impose responsibility on the right party.[126] Limiting itself to just those causes that are "material" may in fact better uphold its moral underpinnings; the law does not, after all, concern itself with trifles. It is also of note that the materiality threshold is not unduly burdensome; the Court in

[120] See *Barker v Corus (UK) Ltd*, above n 31, at [17] and [59]; and *Sienkiewicz v Greif (UK) Ltd*, above n 31, at [103] and [165].

[121] *Fairchild v Glenhaven Funeral Services Ltd*, above n 30, at [64].

[122] *Barker v Corus (UK) Ltd*, above n 31, at [64].

[123] *Sienkiewicz v Greif (UK) Ltd*, above n 31, at [186]. One example is tobacco litigation, where medical science has generally been unable to prove to the requisite standard that smoking caused the claimant's lung cancer, as opposed to another carcinogenic agent. Other examples include background radiation, physical trauma and unwanted pregnancy claims: see generally *McTear v Imperial Tobacco Ltd* [2005] CSOH 69; *AB and others v Ministry of Defence* [2012] UKSC 9, [2013] 1 AC 78; *Fitzgerald v Lane* [1987] QB 781 (CA); and *Wootton v J Docter Ltd* [2008] EWCA Civ 1361, [2008] All ER 256.

[124] *Fairchild v Glenhaven Funeral Services Ltd*, above n 30, at [47] and [108].

[125] Per Laleng "*Sienkiewicz v Greif (UK) Ltd* and *Willmore v Knowsley Metropolitan Borough Council:* A Material Contribution to Uncertainty?" (2011) 74 The Modern Law Review 767 at 787.

[126] At 787.

Sienkiewicz considered that it merely denoted a contribution that was more than *de minimis*.[127]

Therefore, it would seem that probabilistic causation is not only an approach that is more scientifically sound than its deterministic alternative, but also one that a court could feasibly apply. This is not to say that it would need to be applied in all cases. As Gold has stressed, "the boundaries of the solution need not extend beyond the boundaries of the problem".[128] Just as quantum mechanics did not render Newtonian physics useless for describing the motion of objects in the macro world, probabilistic causation would not preclude the use of the but-for test in cases where a macroscopic approximation is appropriate.[129] Probabilistic causation would only need to be applied where either: 1) the process is itself ontologically indeterministic; or 2) science is incapable of knowing the true mechanism underlying the process, and of identifying a traditional but-for cause.

B Application to Climate Change

As was canvassed in Part II, climate change is one area where the deterministic but-for test falls short.[130] Not only is there no signature marker that allows us to trace a climactic event back to a particular corporate defendant's emission,[131] but there is no means of knowing with any certainty whether a particular climactic event was merely a naturally occurring phenomenon that would have occurred even in the absence of climate change.[132] Therefore, it falls now to be examined whether adopting a probabilistic test for causation would improve the prospects of a climate change plaintiff. I propose that there is indeed a way that climate science and probabilistic causation can be reconciled in a plaintiff's favour.

1 Bypassing specific attribution

For a plaintiff to have any success, the first thing that needs to be addressed is the preoccupation that courts have displayed with trying to identify a specific link between defendant A's emission and plaintiff B's harm.[133] I propose that this focus is misplaced. This is because we are not concerned with an individualised process with a linear causal chain from A's emission to B's harm, but with a complex, *global* process.

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[127] *Sienkiewicz v Greif (UK) Ltd*, above n 31, at [107].

[128] Gold, above n 87, at 319–320.

[129] At 320.

[130] See Peñalver, above n 28, at 582 and 586–587.

[131] Grossman, above n 28, at 24.

[132] Kysar, above n 6, at 31; Grossman, above n 28, at 24; and Peñalver, above n 28, at 581–582.

[133] See generally *Lliuya v RWE AG*, above n 13.

Drawing again on the "bash/clash/slash" situations with which tort law has traditionally been concerned, judges are used to dealing with cases in which there is a linear, individualised and often observable chain connecting the particular defendant to the particular claimant's harm.[134] In the context of climate change, therefore, judges seek to identify a comparably clear link. There are two reasons this is problematic.

First, the very assumption that a linear chain connecting the particular parties is capable of being identified is deterministic. It assumes that, at each 'kink' in the causal chain, input A invariably produces output B, such that we can eventually develop a clear picture of the link between the defendant and the plaintiff.[135] As I have explained, this is not necessarily the case.

Secondly, climate change is not an individualised process, but a cumulative one. One cannot, therefore, expect to identify the traditionally dyadic link. This does not, however, suggest that there is no causative relationship. The greenhouse effect is a global process caused by the atmospheric accumulation of emissions worldwide.[136] Every person who releases emissions into the atmosphere contributes to that process. If that global process then goes on to cause harm, it is only logical that each one of its contributors be capable of being identified as a cause. This was in fact recognised by the Essen District Court in *Lliuya*, the Judge writing, "[E]very single emission of greenhouse gases is to contribute to climate change. Thus, with regard to climate change, the causal relationship is putatively more firmly settled".[137]

New Zealand's Environment Court made similar observations in *Environmental Defence Society Inc v Taranaki Regional Council.*[138] The Judge considered that while "it [was] not

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[134] Wright, above n 93, at 52.

[135] Brennan, above n 55, at 482.

[136] See Intergovernmental Panel on Climate Change "Summary for Policy Makers" in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2014) at A.1.

[137] Climate Case Chart, above n 13, at 6–7. It was rather the lack of a traditionally linear causal chain that led the Judge to reject the claim. This is not something with which we are concerned under a probabilistic approach.

[138] *Environmental Defence Society Inc v Taranaki Regional Council* EnvC Auckland A184/2002, 6 September 2002. This dispute took place in the context of seeking resource consent under the Resource Management Act 1991, s 3 of which expressly defines 'effect' as including "any cumulative effect which arises over time or in combination with other effects". This statutory context was likely influential in the Court's adoption of a less individualised and more cumulative understanding of climate change.

possible for science to identify any definable effects attributable to the carbon dioxide discharge from the [relevant] site, locally, regionally or globally",[139] "because of the stable nature of carbon dioxide and the fact that each small contribution is spread around the globe to combine and create the greenhouse effect … the effect of the proposed plant will nevertheless be more than "de [minimis]" or vanishingly small".[140] The Judge therefore found that the defendant's proposed activities, through their contribution to global warming, could cause significant adverse changes to the global environment.[141] This passage was endorsed by Elias CJ in her dissent in *West Coast ENT Inc v Buller Coal Ltd*.[142]

With this in mind, the central issue therefore becomes whether climate change – as contributed to by all emitters – caused the plaintiff's harm. It is here that the value of probabilistic causation becomes clear.

2 Climate change as 'the cause'

As canvassed earlier, a critical obstacle to the success of climate change plaintiffs under the deterministic model of causation is that all of the effects often attributed to climate change also have a background rate of occurrence, independent of global warming.[143] Therefore, whether the effect would still have occurred but for the action of climate change cannot be resolved with any certainty.[144] Science cannot look at a storm, for example, and somehow identify a signature attribute that points to its being a product of climate change.[145] This is precisely the sort of causal indeterminacy that makes probabilistic causation appropriate.[146] Regardless of whether the mechanism itself is indeterministic or merely appears indeterminate due to science's limited diagnostic powers, a deterministic test would require plaintiffs to prove something that is impossible to prove.

If we were to apply a probabilistic test, all that a plaintiff would need to prove on the balance of probabilities is that climate change increased the probability that the plaintiff's

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Nevertheless, it is useful judicial recognition that climate change is best understood in cumulative and collective terms, rather than at the level of the individual emitter.

[139] At [19].

[140] At [24].

[141] At [23].

[142] *West Coast ENT Inc v Buller Coal Ltd* [2013] NZSC 87, [2014] 1 NZLR 32 at [90]–[91].

[143] Kysar, above n 6, at 31; Grossman, above n 28, at 24; and Peñalver, above n 28, at 581–582.

[144] Peñalver, above n 28, at 582.

[145] Grossman, above n 28, at 24.

[146] See Gold, above n 87, at 280–281.

harm would occur. As *Fairchild* has demonstrated, it is likely that a court would impose a threshold of materiality, such that the increase in probability would have to be more than *de minimis*. By this logic, the defendant's contribution to climate change (and so the increase in risk attributable to them) would also have to be more than *de minimis*.

Climate science is abundant in probabilistic evidence. Two potentially useful sources of such evidence for a climate change plaintiff are the Intergovernmental Panel on Climate Change (IPCC)'s reports and the nascent field of Probabilistic Event Attribution (PEA).

3 IPCC reports

According to Mallon J of the New Zealand High Court, IPCC reports are "the most comprehensive assessment of scientific knowledge on climate change" available.[147] The IPCC's most recent report, the Sixth Assessment Report (AR6), provides a thorough assessment of climate change's risks and impacts, attributing its consequences to numerous causal factors.[148] Many of the assessments it provides are framed in terms of risk and probability.[149]

As an example of how the AR6 could aid a climate change plaintiff under a probabilistic approach, a plaintiff dealing with loss caused by a heatwave could point to the IPCC's finding that it is "virtually certain" (that is, a 99–100 per cent probability) that hot extremes, including heatwaves, have become more frequent and more intense since the 1950s.[150] The "main driver" of these changes, according to the report, is human-induced climate change.[151] This means that humans are "responsible for more than 50 [per cent] of the change".[152] Furthermore, it is stated that "some recent hot extremes observed over the past decade would have been *extremely unlikely* to occur without human influence on the climate system",[153] with the term "extremely unlikely" referring to a 0–5 per cent probability.[154] Thus, a defendant's emissions, having contributed to anthropogenic climate

[147] *Thomson v Minister for Climate Change Issues* [2017] NZHC 733, [2018] 2 NZLR 160 at [10].

[148] See generally Intergovernmental Panel on Climate Change *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate change* (Cambridge University Press, 2014).

[149] Intergovernmental Panel on Climate Change, above n 136, at n 4.

[150] At A.3.1.

[151] At A.3.1.

[152] At n 14.

[153] At A.3.1.

[154] At n 14.

change, could be said to have materially increased the risk of the plaintiff's harm from "extremely unlikely" to the much-heightened risk we see today.

4 PEA studies

Though still an emerging field of research, PEA studies could be another avenue of interest. These studies compare how often a particular extreme weather event occurs in two model climate scenarios, one of which features the "world as it is" (with anthropogenic emissions), and the other of which represents the "world that might have been" (without anthropogenic emissions).[155] From this, it can be calculated by what factor climate change increased the risk of the relevant event and, by extension, the plaintiff's harm. For example, a PEA study of river runoff (used as a measure of flooding) in England and Wales revealed that in the "world as it is" the chance of exceeding the critical runoff threshold was one-in-ten a year.[156] The chance of the same in the "world that might have been" was more like one-in-twenty.[157] Thus, it could be concluded (albeit with a large range of uncertainty) that emissions increased the risk of flooding by a factor of two.[158] Again, such evidence could feasibly convince a factfinder that climate change materially contributed to the plaintiff's harm.

Probabilistic causation could therefore be an effective solution to climate change plaintiffs' causal woes. Not only does it dispense with the need to apply a deterministic test to a factual scenario with which it is incompatible, but the probability and risk-based evidence afforded by climate science also lends itself to such an analysis. A probabilistic approach should, on this basis, be welcomed.

V Conclusion

Proof of causation need not be an obstacle to the success of climate change tort claims. Indeed, when causation is viewed through science's lens, it becomes clear that the resistance with which these claims have been met is a product of the law's insistence on a simple fallacy, which science has long abandoned. If lawyers were to follow in scientists' footsteps, and forego its deterministic but-for test in favour of probabilistic causation, litigants could have a real chance of success.

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[155] Friederike Otto, Rachel James and Myles Allen *The Science of Attributing Extreme Weather Events and its Potential Contribution to Assessing Loss and Damage Associated with Climate Change Impacts* (Environmental Change Institute) at 2.

[156] At 2.

[157] At 2.

[158] At 2.

That said, the path is not yet clear. While the application of a probabilistic test for causation has the potential to resolve most of the causal inquiry, a court is still likely to impose a threshold of materiality on the defendant's contribution before it will be satisfied of causation.[159] As a defendant's emissions will often be "miniscule in the context of … global greenhouse gas emissions",[160] a claimant may well have difficulty convincing a court that their emissions were more than *de minimis*. While this remains a question for further research, a few preliminary suggestions can be made as to possible solutions.

First, Holt and McGrath have suggested that framing emission contributions around the 'Carbon Budget'[161] could help courts to view them as more than a "drop in the ocean".[162] This suggestion was looked upon favourably by Winkelmann CJ, Glazebrook and France JJ, writing extra-judicially.[163] Second, Professor Douglas Kysar has suggested that framing climate change in terms of tipping points – "greenhouse gas concentration thresholds beyond which runaway climate change scenarios may occur" – may help to "make tangible the way in which discrete contributions to the problem matter, even though they only appear as proverbial drops in a bucket".[164] A recent judgment of the Federal Court of Australia indicates that reliance on a tipping point analysis could indeed help.[165] Therefore, while this is something that requires further exploration, *de minimis* arguments do not seem insurmountable.

Ultimately, now is a critical time in the planet's history. The AR6 finds that unless significant reductions in CO_2 and other greenhouse gas emissions are made in the coming decade, the earth will continue to warm far beyond the Paris Agreement target of 2ºC, and

[159] See *Fairchild v Glenhaven Funeral Services Ltd*, above n 30, at [42].

[160] *Smith v Fonterra Co-Operative Group Ltd*, above n 14, at [82].

[161] Defined as "the estimated cumulative amount of global carbon dioxide emissions that is estimated to limit global surface temperature to a given level above a reference period": Intergovernmental Panel on Climate Change *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (2018) at 544.

[162] Holt and McGrath, above n 5, at 20.

[163] Winkelmann, Glazebrook and France, above n 5, at [88].

[164] Kysar, above n 6, at 51.

[165] In *Sharma*, Bromberg J adopted the plaintiffs' proposal of a "tipping cascade" analysis, finding that "in the context of there being a real risk that even an infinitesimal increase in global average surface temperature may trigger a [tipping cascade], the [defendant's] prospective contribution is not so insignificant as to deny a real risk of harm to the [plaintiffs]": *Sharma v Minister for the Environment*, above n 16, at [259]–[253].

experience a cascade of catastrophic effects.[166] As climate change plaintiffs continue to bring actions challenging our largest corporate emitters, alternative approaches to causation need to be explored. Science may well have the answer.

[166] Intergovernmental Panel on Climate Change, above n 136, at B.1.

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