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| RESEARCH ARTICLE

Climate Attribution Litigation: Holding Emitters Accountable

Novera Bhatti
Masters in Law (LLM), DePaul College of Law, Chicago, IL, USA
Corresponding Author: Novera Bhatti, **E-mail**: novera.bhatti1998@gmail.com

| ABSTRACT

This is the absence of accountability between massive carbon emissions by industrial activities and the reported climate damage, which is one of the most impactful governance failures of modern times. Although the scientific evidence of most anthropogenic greenhouse gas emissions can be traced to a few identifiable producers of fossil fuels**,** the so-called carbon majors have theoretically immature and practically inadequate legal mechanisms through which the afflicted communities could seek redress, and have been fragmented. The article fills a key theoretical gap in the current body of literature: the literature on attribution science, climate litigation, corporate accountability, and climate governance has proceeded to develop individually, but no single theoretical model has ever brought together these four strands into a consistent accountability structure of emitter accountability. This article creates such a framework by relying on a systematic conceptual review of peer**-**reviewed scholarship in environmental law, climate science, governance theory**,** and tort doctrine. It is theorized that, when incorporated with the changing legal standards in causation and corporate knowledge-liability theory and climate governance theory, climate attribution science facilitates the creation of a plausible and analytically sound attribution chain between large emitters and reported climate damage and actionable claims to remedy. The article connotes four conceptual findings: causal-legal accountability chain; the typology of legal barriers and the theoretical resolutions; the nexus of corporate knowledge-deception-liability; and the reparative architecture in loss and damage with legal redress. These results are pulled together into a coherent and multi-strand theoretical model of emitter accountability arranged into four analytically separate strands of scientific accountability based on attribution, legal accountability based on tort and human rights, moral accountability based on the knowledge-deception nexus, and governance accountability based on litigation as a regulatory tool. With the rising development of attribution science and increasing judicial faith in probabilistic causal evidence, attribution litigation targeting climate change has an opportunity to rapidly become not just a fringe enforcement tool, but a structural-level implementative instrument of climate accountability with implications to both legal science and climate justice movement, and global regulation design.

| KEYWORDS

Climate attribution science; climate litigation; emitter accountability; carbon majors; loss and damage; climate governance

| ARTICLE INFORMATION

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1. Introduction

The sheer magnitude of the worldwide climatic crisis and the recognizability of its main culprits have developed an existent and ever-growing accountability paradox. Scientific studies have now pinpointed most past greenhouse gas emissions to a narrow group of large industrial carbon emitters, and has conclusively proven that the use of fossil

fuels by a select few companies has contributed to the rise of global surface temperatures, to sea-level rise, and to the frequency and intensity of extreme weather events (Heede, 2014; Ekwurzel et al., 2017). But in spite of this scientific eloquence, the legal systems of various nations in the world have been unable to convert traceable emissions into legally enforceable responsibility. Not only have fossil fuel corporations not shouldered the burden of the damages caused by their products, in most of the recorded cases they have actively strived to avoid the awareness by society of such damages (Franta, 2018; Supran and Oreskes, 2017). What comes out of it is a governance gap of unprecedented importance: the very parties that have contributed to anthropogenic climate change to the largest extent have so far almost entirely avoided legal responsibility.

Climate attribution science has taken the place of this void of accountability as a potentially revolutionary tool of the law. The science of attribution as a methodological approach of linking particular weather conditions, temperature changes and climate-related damages to anthropogenic forcing of greenhouse gases provides the technical plumbing of a new era of climate litigation. Attribution science contributes to the evidentiary basis of courts by offering them the causal chain between emissions and harm through which courts can hear identity claims of liability whose prior effort to excite by establishing causation across the diffuse emissions globally and local harm at a specific point foundered (Burger and Wentz, 2020; Marjanac and Patton, 2018). The legal opportunities created by this science were not overlooked: the world mass of climate cases has been increasing exponentially, and an increasing number of cases are directed to the particular actions of fossil fuel companies (Setzer and Vanhala, 2019; Peel and Osofsky, 2020).

Nevertheless, the new body of litigation is based on theoretical premises which are yet to be developed. Along with other sections of research, the current literature has explored the facet of attribution science, climate litigation doctrine, corporate moral responsibility, and climate governance as independent investigations, yet has not adequately theorized an integrated framework that connects these strands into a coherent model of emitter accountability. The logic of causality between the emissions tracing and the legal standard of causation, the alternative scientific probability and the doctrinal liability, the effect of corporate deception on aggravated responsibility and the connection between litigation and global climate regulation have not been combined in a single theoretical framework. This theoretical gap is the gap that is filled by this article.

The aim of the research of this article is thus to come up with a theoretical and conceptual framework in the comprehension of how the role of climate attribution litigation can be used to hold large industrial emitters responsible in the recorded climate damage. This goal is sought by following a methodical conceptual search of the pertinent scholarly literatures synthesised by use of a thematic analysis and theoretical triangulation. The article goes further in the following way. In section 2, a thematic literature review is given in five major domains. Section 3 defines the conceptual approach. Four conceptual and theoretical findings are introduced in Section 4. In section 5, these findings are addressed in terms of climate governance theory and generalised into a single multi-strand model of emitter accountability. Section 6 ends with an overview on the transformative power of attribution litigation.

2. Literature Review

2.1 The Framework of Carbon Majors and Emissions Tracing.

The conceptual base of attribution-based emitter responsibility is anchored on a literature of studies that have tediously followed the historical contribution of greenhouse gases to recognizable industrial sources. A ground breaking study by Richard Heede in 2014 determined that about two-thirds of total industrial carbon dioxide and methane emissions since the mid-nineteenth century could be placed into 90 actors the carbon majors allowing responsibility, rather than diffuse and impossible to allocate, to be placed empirically in one place on a set of producers (Heede, 2014). This discovery was so fundamental since it redefined the climate problem as an amorphous collective action failure instead of a solvable producer liability inquiry. Later studies by Heede and Oreskes generalized this model and assessed the amount of emissions stranded in the fossil fuel reserves of these

corporations, quantifying the magnitude of future damage that was entrenched in current corporate resources and created a prospective and retrospective aspect of emitter responsibility (Heede and Oreskes, 2016).

This was further refined by Ekwurzel and other researchers who empirically related the emissions attributed to key carbon emitters with particular physical climatic consequences - recorded rises in atmospheric carbon dioxide levels, average surface temperatures, and sea level, and developed a direct scientific connection between identifiable corporate output and quantifiable global damage (Ekwurzel et al., 2017). Most recently, Grasso and Heede have applied the carbon majors model to reparative justice, asserting that the scope and frequency of emissions by large fossil fuel corporations together with their prior knowledge of the implications presents a moral and legal platform of reparation to climate-impacted communities (Grasso and Heede, 2023). This body of literature, when put together, sets up both the empirical and normative frameworks of attribution-based litigation.

2.2 The Attribution Science and Legal Causation.

One of the most challenging interfaces in modern environmental law, whereas it is concerned with the doctrine, is the translation of attribution of physical climate into legal standards of causation. Attribution science comes up with probabilistic estimates of the degree to which anthropogenic greenhouse gas emissions have contributed to the probability or extent of occurrence of specific climate events; it does not, in the classical sense, show that an individual storm, flood or drought would not have happened, but due to the emissions. This probabilistic nature may be somewhat irreconcilable with classical but-for causes of action, where a plaintiff must prove that the damage would have not arisen without the conduct of the defendant (Burger and Wentz, 2020; Lahr, 2021). Marjanac and Patton have contended that the binary form of but-for causation is at least a doctrinal construct that does not necessarily require being treated as fixed, and have suggested that some alternative forms of causation, such as material contribution to risk, substantial factor tests, and proportionate liability, are hypothetically capable of dealing with the probabilistic products of attribution science (Marjanac and Patton, 2018).

It may be the greatest contribution to this interface made by Stuart-Smith and others, who have shown that attitudinal science, especially when applied to extreme weather events, had evolved to a stage in which it could fill in certain obvious gaps in the evidence that had been pointed out in climate litigation (Stuart-Smith et al., 2021). Quilcaille and co. have gone even further and attributively systematized the issue of heatwave events through the specific contribution of carbon majors, which constitutes a producer-to-harm causal pathway in a level of granularity that is directly actionable in litigation (Quilcaille et al., 2025). Otto and co-authors have explored how the theme of attributing historic responsibility to extreme weather events can be organized within the prevailing climate governance models, which contain both physical and normative distribution of responsibility (Otto et al., 2017). Mayer has highlighted how attribution science applies to governance in the context of developing duty of care principles that can be applied to fossil fuel firms (Mayer, 2022b).

2.3 Climate Change Litigation Overview.

The climate change litigation environment in the world has been revolutionised in the last 20 years. The initial cases were largely against state actors, and were aimed at forcing governments to implement stricter policies on emission reduction; however, the modern litigation environment is characterized by much greater variety of litigants and defendants (Setzer & Vanhala, 2019). The corporate defendants, in particular fossil fuel companies, now have become the participants of climate suits that are initiated in various jurisdictions, with the plaintiffs including not only municipalities and states but also civil society organisations and individuals (Peel & Osofsky, 2020). Ganguly, Setzer, and Heyvaert have followed the development of the corporate climate litigation and the legal theories, procedure choices, and jurisdictional courses in which claimants have pursued to hold companies responsible in contributing to climate harm (Ganguly et al., 2018). A survey conducted by Burger and Gundlach in different parts of the world enumerated the size, geographic distribution, and legal nature of climate cases being brought in the early 2000s, and the survey has continued until the middle of the 2010s (Burger and Gundlach, 2017).

Alogna and others have carried this treatment further to give a detailed comparative treatment of climate litigation in major legal systems, shedding light in the ways diverse doctrinal traditions and rules of procedure generate greater or lesser accessibility by claimants to corporate accountability (Alogna et al., 2021). More importantly, Sato and co-authors have also shown that the effects of so-called climate litigation already have a quantifiable deterrence effect on corporate behaviour, and that firms subjected to litigation, or incurring market losses through the threat of litigation, experience substantial declines in their market value, thus confirming the role of litigation in governance in the absence of its legal consequences (Sato et al., 2024).

2.4 Business Fraud and Ethical responsibility.

A literature has shed light on an aspect of emitter responsibility beyond simple laxity towards a more serious form of responsibility the reported prior awareness of large fossil fuel corporations on the climate impact of their offerings, along with active and long-lasting disinformation initiatives aimed at postponing public realization and government action. The historical work of Franta has determined that the oil industry had known back in the late 50s of the previous century that CO2 emissions were correlated with global warming and such knowledge circulated internally but contradicted publicly in the years to come (Franta, 2018). In a systematic study of internal and external climate communications by the ExxonMobil between 1977 and 2014, Supran and Oreskes have shown that there is statistically significant gap between what the scientists at the company knew and what the company was saying to the public - a trend they describe as a kind of climate disinformation (Supran and Oreskes, 2017). Franta has also reported how the industry has strategically employed the use of economic consultants to create and spread studies aimed at obstructing climate policy (Franta, 2021).

2.5 Loss, Damage and Reparative Justice.

The institutionalization of climate loss and damage as a novel conceptual and normative category has presented new theoretical possibilities of responsibility among emitters. Among others, Boyd and co-authors have suggested that loss and damage, which refers to economic and non-economic harms caused by climate change, including those that exceed the boundaries of adaptation, is also a new policy frontier that requires a radically different reparative logic than the paradigms that have traditionally dominated climate governance, namely mitigation and adaptation (Boyd et al., 2021). Grasso and Heede have operationalised this framework with reference to the carbon majors, whereby they contend that the quantifiable traceable emissions of major fossil fuel companies can form the basis of reparation that is scientifically credible and also ethically compelling, especially due to the established foreknowledge of the companies (Grasso & Heede, 2023). Verheyen and Franke have applied the concept of loss and damage to the international liability doctrine, looking at the legal activities by which both state and non-state actors may make reparative claims on transboundary climate damage (Verheyen & Franke, 2022).

2.6. Determining the Theoretical Gap.

Taken as a whole, these five bodies of literature point to an existing theoretical gap. The progress of each strand has been systematic, but the gaps between them have not been theorised. There is no current framework that combines the precision of emissions tracing found in the carbon majors literature, the logic of causality through probability found in attribution science, doctrine development chain found in the literature on litigation, aggravated liability implications found in the literature on corporate deception, or the development of a reparative architecture found in the literature on loss and damage into a single, coherent theoretical framework of emitter responsibility. The gap is directly dealt with by this article which develops such a model by systematic conceptual synthesis.

3. Methodology

The systematic conceptual and theoretical review approach of the article is based on an interpretive, theory-building epistemology. The philosophical direction of the study is grounded in three intellectual traditions, namely, legal theory, which offers the methodology of doctrinal analysis and normative reasoning; the science and technology studies, which offers the tools to analyse the construction and social implementation of the scientific knowledge in the regulatory setting; and the climate governance scholarship, which places legal instruments in the

framework of a multi-level structure of global climate policy. The traditions are not viewed as substitutes but rather complementary analytical prismatic lenses that help shed light on various aspects of the emitter accountability problematic.

The conceptual review process entailed a systematic searching and integrating peer-reviewed literature in four disciplinary areas, including physical climate science and attribution methodology, environmental and tort law, corporate accountability and business ethics, and international and comparative climate governance. The identification of the literature was based on the search of the following databases: Scopus, Web of Science, HeinOnline, Google Scholar, and Social Science Research Network (SSRN). Keywords used were the following (and a combination of): climate attribution science, climate litigation, carbon majors, emitter liability, loss and damage, duty of care fossil fuels, and climate governance. This search was restricted to the years 2000 to 2025, but focused especially on the last 2014-2025 during which the cross-disciplinary literature combining attribution science and climate litigation has produced the most substantive cross-disciplinary literature. A preliminary list of sources (about 180) was found; and with the inclusion criteria (relevant to emitter accountability, participation in the attribution science or climate litigation doctrine) the list was narrowed down to 25 selected sources to undergo systematic synthesis.

The two complementary methods that were used in the analytical strategy were thematic synthesis and theoretical triangulation. Thematic synthesis entailed coding of the reviewed literature based on repeated analytical themes causation criteria, legal impediment, corporate knowledge, reparative frameworks, governance functions and building cross-cutting conceptual propositions by integrating the insights of multiple sources. Theoretical triangulation implied testing every emergent theoretical proposal with two or more conceptual frameworks of a discipline, and finding places of productive tension and mutual reinforcement. Where fields produced conflicting implications, these strains were discussed as analytically fruitful as opposed to issues that should be settled by privileging one of the traditions over the rest.

The objective of this article suits a conceptual methodology since there is no need to test hypotheses on the basis of empirical data but to build the theory. The study question of how can climate attribution litigation be used to put big emitters to blame is essentially a question of logical and normative fitness of a series of legal and governing arguments. In this regard, the article does not purport to produce new empirical findings. Its services are speculative: it is the building of conceptual models, typologies, and integrative systems that can be used to inform future empirical research and theological growth. Future empirical support of the theoretical model suggested in this paper is achieved by conducting case studies and comparisons of various legal studies.

4. Results

4.1 Findings 1. The Causal-Legal Accountability Chain.

The initial and the main conceptual discovery of this review is the discovery and theoretical development of what can be described as the Causal-Legal Accountability Chain - a stepwise conceptual framework of the course of action of industrial emittance to a legal solution. This chain is shown in Figure 1 in the form of a conceptual flow diagram consisting of 6 interdependent nodes: Emissions Tracing - Physical Climate Attribution - Legal Causation Standards - Duty of Care - Liability Determination - Remedy and Reparation.

Figure 1. The Causal-Legal Accountability Chain of Climate Attribution Litigation.

01	EMISSIONS TRACING	Assignment of historical GHG emissions to recognisable industrial emitters with carbon major methodology. Maas that accountability has the ability to point towards a specific group of actors instead of a source of anonymity (Heede, 2014; Ekwurzel et al., 2017; Heede and Oreskes, 2016). ▼
02	PHYSICAL CLIMATE ATTRIBUTION	climate attribution Connection of producer-level emissions to particular measurable physical climatic effects - high temperatures, stronger storms, sea-level rise, more intense droughts - using probabilistic attribution methodology (Quilcaille et al., 2025; Stuart-Smith et al., 2021; Otto et al., 2017).
03	LEGAL CAUSATION STANDARDS	Reconverting probabilistic instances of attribution into legal causal instances. Conflict between scientific probability and binary but-for causation treated using material contribution to risk, substantial factor analysis, and proportionate liability theories (Burger and Wentz, 2020; Marjanac and Patton, 2018; Lahr, 2021). ▼ frameworks (Burger & Wentz, 2020; Marjanac & Patton, 2018; Lahr, 2021).
04	DUTY OF CARE	It is the normal judicial finding that the defendant was a party to a legal duty to act reasonably to prevent harm to climate. Basing it on the negligence doctrine and human rights paradigms; operationalized in landmark duty of care jurisprudence (Mayer, 2022a; Macchi and van Zeben, 2021).
05	LIABILITY DETERMINATION	Judicial determination of whether the causal chain of element and duty of care yield the conclusion of legal liability on the part of the defendant emitter. Includes threshold tests on foreseeability, breach, and proximate cause in any legal system (Alogna et al., 2021; Peel and Osofsky, 2020).
06	06 REMEDY and REPARATIONS	Instances of relief that may be offered upon finding a successful liability: compensatory damages in the form of quantifiable losses; an injunction in the form of reduction of emissions; reparative mechanisms to support adaptation; transformative orders to reorganize corporate behavior (Boyd et al., 2021; Grasso and Heede, 2023; Verheyen and Franke, 2022).

Note. This theoretical process flow chart shows the hypothetical line of thought of industrial emissions source to legal redress and compensation, which goes through six mutually supporting nodes. Every arrow symbolizes an abstract shift that was possible due to the combination of attribution science and the changing legal doctrine. Reference: The synthesis of the concept of the author.

The Emissions Tracing node is the initial node, and it consists of the scientific and archival tradition of assigning historical greenhouse gas emissions to a particular set of industrial producers. Based on the literature on carbon majors (Heede, 2014; Ekwurzel et al., 2017; Heede and Oreskes, 2016), this node entrenches the factual basis of all further accountability arguments, the fact that the emissions at issue are not unknown or anonymous but can be attributed with reasonable accuracy to identifiable parties. Physical Climate Attribution is the second node that links the emissions produced at the producer level with particular physical climate consequences based on the probabilistic attribution science approaches (Quilcaille et al., 2025; Stuart-Smith et al., 2021; Otto et al., 2017). This is the scientific linking node between the register of emissions and the suffering of injury.

The third node is Legal Causation Standards that is the most doctrinaire in the chain. It is a process through which the attribution science yields probabilities that are converted into the legal process causal evidence needs. The probabilistic logic of climate science and the traditionally binary nature of but-for causation have been theoretically antagonistic to each other, and partially resolved in the literature (Burger and Wentz, 2020; Lahr, 2021; Marjanac and Patton, 2018). Duty of Care is the fourth node that is the normative legal finding that the defendant had a legal duty towards the plaintiff in order to prevent the action leading to the harm. The conceptual foundation of duty of care has been expressed as both in negligence doctrine, as well as in the human rights models, most notably in the Milieudefensie v. Royal Dutch Shell litigation (May, 2022a; Macchi and van Zeben, 2021). Liability Determination is the fifth node, and it reflects the judicial determination of the existence of a finding of legal liability by the established causal chain and duty of care. The sixth and last node is Remedy and Reparation, which is the categories of relief that can be awarded in case of a successful finding of the liability (Boyd et al., 2021; Grasso and Heede, 2023; Verheyen and Franke, 2022).

4.2 Finding 2 Typology of Legal Obstacles to Climate Attribution Litigation.

The second conceptual discovery is the legal impediments that have traditionally hampered the actualisation of the accountability chain outlined in Finding 1. A literature review of the climate litigation literature indicates that a specific and recurring set of doctrinal obstacles each has certain theoretical implications and possible theoretical solutions. Such barriers do not just amount to practical challenges but are structural attributes of legal systems which were not initially structured with climate accountability as a policy goal. The threshold problem is standing: it requires a legally recognised plaintiff who can prove a particularised, traceable, and redressable injury before the accountability chain can be brought to the court of law. Attribution science is becoming a more effective tool to create regionalised claims of injury because it allows attributing particular regional climate effects to particular emitter outputs (Stuart-Smith et al., 2021). The second significant impediment is the causation gap that is talked about in Finding 1. The challenge of the political question doctrine puts a unique problem by placing climate policy as a legislative, not judicial determination issue. Jurisdictional fragmentation shows the transnational incompatibility between the transnational nature of emissions and local form of the national legal system (Alogna et al., 2021). Lastly, the problem of evidentiary gaps has always discouraged claimants and courts, but due to the rapid development of attribution methodology, this gap is becoming smaller (Quilcaille et al., 2025). These barriers are given in a tabular format in Table 1 below.

Table 1. Typology of Legal Barriers to Climate Attribution Litigation

Legal Barrier	Description & Doctrinal Basis	Theoretical Resolution Pathway	Current Doctrinal Status
Standing	Plaintiffs should prove a traceable, specific and redressable injury. This diffuse, collective, and temporally extended nature of the harm of climate generates a basic tension. with standing on individuated injury based doctrines.	Attribution science facilitates the building of particularised claims of injuries by associating local climate effects that can be quantified in terms of temperature increase, more intense flooding occurrences to the emitter outputs that can be identified. In this instance, (Stuart-Smith et al., 2021; Ganguly et al., 2018) serves as the source of background	Progressive: individualisation of climate harm is narrowing this barrier increasingly on a jurisdiction-by-jurisdiction basis (Peel & Osofsky, 2020).
Causation Gap	Conventional but-for causation would demand evidence that the injury could not have taken place in the absence of the particular behaviour of the defendant - a requirement that probabilistic attribution science fails to meet in its binary incarnation.	Theoretically, alternative causation theories such as material contribution to risk, substantial factor analysis, and proportionate liability can accept probabilistic attribution results (Marjanac and Patton, 2018; Burger and Wentz, 2020).	Developing: several courts have started to admit risk-based causation standards; the entire doctrine needs more development of judicial norms (Lahr, 2021).
Political Question Doctrine	In certain jurisdictions, courts have rejected climatic claims as unjustifiable political issues, and described emissions policy as a legislative concern. rather than judicial determination.	The theoretical limit of judicial is found in the difference between the judgment of polycentric policies (non-justiciable) versus the adjudication of the legal obligations of identifiable plaintiffs (justiciable). engagement with climate responsibility statements (Alogna et al., 2021).	Partly settled: the Milieudefensie v. Shell decision shows that the claim of corporate duty of care is judicially cognisable in cases where the policy of emissions is not (Mayer, 2022a).
Jurisdictional Fragmentation	The international nature of emissions and transnational nature of emitters, communities impacted and stored information poses a structural inability of the national legal systems	The schemes of mutual legal assistance, the claims of universal jurisdiction, and the emergence of transnational human rights litigation offer partial solutions; finally, binding international tools are needed (Casino et al.,	Unresolved: the most structurally intractable obstacle; has to be reformed internationally by international law courts which are beyond the reach of local courts (Verheyen & Franke, 2022).

Legal Barrier	Description & Doctrinal Basis	Theoretical Resolution Pathway	Current Doctrinal Status
	with the territorial character of the law.	2022; Alogna et al., 2021).	
Evidentiary Gaps	The technical character of the science of attribution, the lack of standardised evidentiary forms of attribution results and the lack of familiarity of the courts with the probabilistic evidence, have been historically off-putting to claimants and courts.	This obstacle is increasingly being lessened due to the rapid development of attribution methodology especially the ability to assign individual corporate manufacturers to specific significantly extreme events and accumulating harms (Quilcaille et al., 2025; Stuart-Smith et al., 2021).	Constricted quickly: every form of new attribution study decreases the gap in evidence; judicial education programs and the structure of expert witnesses are additional strategies (Wentz et al., 2023).

Note. Source: Synthesised based on Stuart-Smith et al. (2021); Ganguly et al. (2018); Marjanac and Patton (2018); Burger and Wentz (2020); Lahr (2021); Alogna et al. (2021); Quilcaille et al. (2025); Wentz et al. (2023); Peel and Osofsky (2020); Mayer (2022a); Verhey

The theoretical relevance of this typology is both in grouping known barriers and in indicating that there is a conceptually consistent way through which each of the barriers can be resolved. None of these barriers is absolute; they are all artifacts of doctrines of legal systems that were not even intended to accommodate the structure of causation of climate harm, and each can be gradually overcome by a combination of the growing science of attribution, doctrinal development, and designing legal litigation.

4.3. Findings 3: The Corporate Knowledge-Deception-Liability Nexus Finding

The third conceptual conclusion is the exacerbated nature of emitter liability, taking into account the known industry information and intended misinformation. What the scholarship discussed in Section 2.4 creates is a pattern of conduct that transcends the normal kind of negligence and even borders something resembling a fraudulent concealment one can knowingly suppress and misrepresent material information. Franta shows that the history of oil giants has shown that they have valid scientific understanding of the risks of climate decades before it became publicly recognized (Franta, 2018). A systematic examination by Supran and Oreskes of the communications of ExxonMobil through the prism of four decades depicts a statistically sound trend of intercompany truthfulness and outsourcing of veracity on climate science - a trend that carries literal doctrinal implication on the quality of liability to which such businesses can be held (Supran and Oreskes, 2017). Franta has also recorded how the industry strategically engaged the economic consultants to block regulatory reactions to a threat that was recognized to be real by the industry itself (Franta, 2021).

Theoretically, the result of this finding uplifts the moral character of emitter liability in two aspects that relate to each other. To begin with, the element of knowledge meets the intentionality requirement that is necessary to draw the line between fraudulent concealment and ordinary negligence and place the defendants at a risk of aggravated or punitive damages in jurisdictions where such damages are acknowledged. Second, the deception aspect introduces another causal channel: the plaintiffs that took decisions based on industry-generated disinformation on adaptation, insurance or property were not only injured in the adverse physical effects of emissions, but also in the conscious manipulation of their ad hoc ganglia. This physical-epistemic harm causation reasoning deepens the model of accountability theoretically and has not been yet comprehensively examined in the literature of litigation (Wentz et al., 2023; Macchi and van Zeben, 2021).

4.4 Finding 4: Loss, Damage, and the Reparative Architecture.

The fourth conceptual finding is the theoretical construction of relating the science of attribution to the measurable loss and damage and the reverse relationship between loss and damage and the construction of reparative claims. The loss and damage literature has developed a normative structure of identifying climate harms that cannot be prevented by mitigation or managed by adaptation harms already experienced and will continue to increase as emission paths evolve in the future (Boyd et al., 2021). This theoretical relation to the attribution science is direct, namely: assuming that physical attribution can determine the extent to which certain climate events are brought more or more serious by anthropogenic emissions, and that the latter events lead to certain losses, then the causal relation between emitter behaviour and recovery claim is complete in principle.

Theoretically, three models of climate liability made available through this reparative architecture are worth the distinction. The former is a compensatory scheme, where the responsible parties pay compensation of an equal amount of financial losses they have inflicted through their emissions. The second one is a reparative model, which extends past the element of financial compensation to include a wider range of restitutionary: support of emission infrastructure, community rebuilding and restoration of social and ecological systems lost as a result of climate change (Grasso & Heede, 2023; Verheyen and Franke, 2022). A third and most radical model is a transformative liability model where the outcome of litigation is simply to compensate historical damage or to re-architecturally reform the energy economy, a type of liability where defendants in a lawsuit are required to finance the move towards the abandonment of fossil fuels as a precondition of judicial adjudication or legal settlement. Transformative model is theoretically rooted in the understanding that the power of compensatory payment cannot properly deal with the irreversible climate damage at a large scale; it can only be replaced by the systemic change as the sufficient response (Mayer, 2022a).

5. Discussion

5.1 Litigation as Climate Governance.

The four theoretical conclusions of Section 4 taken together come up with a theoretical framework of emitter accountability that is based on the synthesis of the law of attribution and legal doctrine. The most significant point in the discussion should be the importance of this framework in terms of governance: the point that is, more and more, backed up by both theoretical and empirical evidence, that climate litigation is not simply a legal solution to particular harms but a structural tool of global climate governance. Such a contention transforms litigation into an auxiliary enforcement tool into more of a constitutive component of the new climate responsibility architecture (Setzer and Vanhala, 2019; Peel and Osofsky, 2020). The climate litigation functions of governance are various and discrete and they work in diverse causal mechanisms and at diverse levels of the multi-level system of governance. A systematic typology of these functions is given in table 2 below, by organising them by their description, mechanism of operation, and the level of governance on which they mainly govern.

Table 2. Theoretical Functions of Climate Litigation in Global Climate Governance

Governance Function	Description	Mechanism of Operation	Primary Governance Level & Key Sources
Deterrence	The reputational, monetary and operational expenses of litigation are imposed on emitters that provide incentives of pre-emptive emissions reduction and strategic restructuring.	Market signalling announcements of litigation and the final results of cases lower the valuation of firms sending negative financial signals to maintain a high-emission behaviour.	The Corporate / Market Level is the one that works based on the reactions of investors, insurers, and financial institutions (Sato et al., 2024).
Norm Generation	Criminal adjudications on climate cases formulate and realise the legal norms especially duty of care and corporate climate responsibility that transcends the individual parties in the litigation.	Establishing of corporate climate responsibilities in the judiciary by precedent sets precedent. authoritative and influential power that transforms the normative surrounding of future cases and regulatory action.	International Norms landmark decisions such National Courts. as Milieudefensie v. Shell develops norms that are quoted and implemented in other jurisdictions (Mayer, 2022a; Macchi & van Zeben, 2021).
Regulatory Gap-Filling	In areas that have created gaps of accountability due to legislative and executive inaction, litigation replaces judicial oversight in areas where regulatory regulation on emitter behaviour is lacking.	The judicial review courts use the established law principles (negligence, nuisance, human rights) to apply to conduct about which regulators were unable to take action, and offer accountability in instances where the governance structures have failed..	Policy judicial findings National Courts ↔ Policy National courts exert pressure on legislative advocacy, which in turn creates a feedback loop between the results of litigation and the creation of the laws (Setzer and Vanhala, 2019).
Disclosure Compulsion	Litigation based on discovery activities, legal proceedings-driven mandatory corporate disclosure and reputational incentives compels the open disclosure of formerly hidden information on corporate climate.	Population and release of the peril and execution of lawsuits compel divulgence of inside correspondence, scientific evaluations, and business figures that re-arrange. social and legislative knowledge about emitter behavior.	Corporate Behaviour → Public Discourse information release creates media and civil society pressure which increases the governance effect of individual cases (Franta, 2018; Supran & Oreskes, 2017).
Structural Reform	The results of transformative	Judicial remedy or settlement of law Structural	Corporate Behaviour → Policy Change structural

Governance Function	Description	Mechanism of Operation	Primary Governance Level & Key Sources
	litigation are injunction based on the emission cut which implies the divestment of fossil fuel, the forced introduction of energy transition funds to business by the court, which places the corporate and governmental behavior on climate directly in the form of restructuring..	changes to defendant behaviour are ordered by the injunctive and equitable relief courts on the conditions of legal settlement, or because of judicial remedy, beyond monetary compensation to impose systemic reform.	orders establish compliance infrastructure that has a long-term impact and is lasting (Boyd et al., 2021; Grasso and Heede, 2023).

Note. Source: Synthesised from Sato et al. (2024); Mayer (2022a); Macchi and van Zeben (2021); Setzer and Vanhala (2019); Franta (2018); Supran and Oreskes (2017); Ganguly et al. (2018); Boyd et al. (2021); Grasso and Heede (2023).

The significance of climate litigation as a multi-level government also is conceptualized in Figure 2, where litigation is a mechanism operating simultaneously on five levels of the governance architecture, involving international normative order, national courts, corporate behaviour, public discourse and policy change.

Figure 2. Climate Litigation as a Multi-Level Climate Governance Mechanism

LEVEL 1 INTERNATIONAL NORMS	Climate litigation relies on and strengthens the normative development of international climate commitments (Paris Agreement, UNFCCC) and human rights norms and the corporate due diligence models. International norms are the sources of the normative authority under which national courts are functioning (Daly et al., 2019; Setzer and Vanhala, 2019).
↕ *(norm transmission ↓ | feedback effect ↑)*	
LEVEL 2 NATIONAL COURTS	The decisions that are made by national courts in interpretation and operationalisation of international normative commitments into binding domestic legal commitments. Such high-profile cases include Milieudefensie v. Royal Dutch Shell transfers accountability requirements into enforceable judicial directives (Mayer, 2022a; Peel and Osofsky, 2020).
↕ *(norm transmission ↓ | feedback effect ↑)*	
LEVEL 3 CORPORATE BEHAVIOUR	The judicial rulings convey responsibility cues into corporate behaviour in three ways, including financial deterrence (reduced market value), compelled disclosure (forced release of internal climate information), and structural reform (injunctive orders mandating reduction of emission) (Sato et al., 2024; Franta, 2018).
↕ *(norm transmission ↓ | feedback effect ↑)*	
LEVEL 4 PUBLIC DISCOURSE	The disclosed information and the behavioral change in corporations become the inputs of the public discourse due to media reports, civil

	society involvement, and the attention of investors as the consequences of the high-profile litigation. The influence is that reshaped social stories increase the governance effect of the personal legal results (Supran and Oreskes, 2017; Ganguly et al., 2018).
↕ *(norm transmission ↓ | feedback effect ↑)*	
LEVEL 5 POLICY CHANGE	Normative change at all four levels above eventually puts a policy change because the legislators and the regulators react to the judicial norm development, corporate disclosures and also changes in public opinion. The litigation thus creates regulatory change that does not serve a particular litigant to a case (Setzer and Vanhala, 2019; Boyd et al., 2021).

Note. Downwards arrows represent norm transmission, and upwards arrows represent iterative feedback effects, which represent the non-linear nature of the change in governance under litigation. References: The synthesis of ideas that the author developed.

The initial level of operation of climate litigation as shown in Figure 2 is the level of international norms, both drawing upon and supporting the normative development of international climate commitments, human rights, and due diligence systems. In their adjudication of cases on emitter liability, national courts, as well as interpret, extrapolate international normative commitments into domestic legal commitments. In their turn, their decisions send the accountability signals into the corporate behaviour, and deterrence, disclosure, and structural reform effects, reported by Sato and others, can be seen as the manifestations of this dimension of governance (Sato et al., 2024). The behavioural change of corporates in turn enters the discourse of the population via media and civil society interest created by high-profile litigation and changes the way people narrate the issue on emitter responsibility and climate justice. Lastly, the normative change that is triggered at every one of these tiers ultimately affects policy change, because legislators and regulators became responsive to norm development by a court, to corporate disclosures and opinion shifts on the part of the population.

5.2 Tensions of Theory and Evolution of Doctrine.

The internal tension of the framework created in this paper, does not go unnoticed. The most basic conflict lies between the probabilistic attribution science and the dichotomous standards of the traditional tort law causes. When we apply the language of probability, attribution science can be said to explain that an occurrence was either Y percent more serious or X percent greater probable occasioned by human emissions. Tort law, in its turn, conventionally requires a two-choice solution: was the act of the defendant the cause of harm to the plaintiff, on the balance of probabilities? The shift towards probabilistic increment to binary causation determination is not only a technical challenge but a structural incompatibility, which courts have traversed with more or less theoretical confidence (Burger and Wentz, 2020; Lahr, 2021; Marjanac and Patton, 2018).

This tension has however been resolved theoretically. Courts in several jurisdictions are now starting to appreciate that the binary form of but-for causation is a legal convention rather than logical requirement, and that the standards of causation of complex, multi-party and probabilistic harms can properly differ with that which is used with simple bilateral causation. The cases that resulted in the development of the duty of care jurisprudence include Milieudefensie v. The case of Royal Dutch Shell shows that a court can discern the doctrinal significance of attribution science without the latter having to satisfy some threshold of certainty that it is not engineered to generate (Mayer, 2022a). The next task of future doctrinal development is to design principled norms on how to translate probabilistic attribution into liability determination norms that are scientific, legally consistent and applied unfairly across jurisdictions (Wentz et al., 2023; Alogna et al., 2021).

5.3 The Unified Theoretical Model of Emitter Accountability.

It is now possible to synthesise the four conceptual findings into a single multi-strand theoretical accountability model centred on four analytically distinct yet empirically interrelated strands of accountability. The first one is scientific accountability by attribution: the methodical attribution of emissions to particular producers, combined

with the physical attribution of climate damage to the emissions, brings about a scientifically based accountability connection between emitters and impacted populations. The development of attribution science and especially its ability to give certain extremes and cumulative harms to individual corporate producers (Quilcaille et al., 2025; Ekwurzel et al., 2017) implies that the scientific strand has become a significant one.

The second one is legal responsibility based on tort and human rights. This strand reifies the relationship of scientific responsibility in the courts, to render attribution evidence into the currency of causation, duty, breach and remedy of the doctrines. The developing jurisprudence of climate litigation is the progressive unification of such strand (Burger and Gundlach, 2017; Ganguly et al., 2018; Mayer, 2022a; Macchi and van Zeben, 2021). Moral responsibility is the third strand as a result of knowledge-deception nexus. Moral claim of accountability generated by the documentation of industry foreknowledge and intentional disinformation (Franta, 2018; Supran and Oreskes, 2017; Franta, 2021) generates an essential part of the argument that proves to be morally compelling even where legal requirements of proof are not fulfilled, and which can independently impact the discourse and regulation at the societal level, without references to court decisions. The fourth one is accountability of governance by litigation as regulating tool. This strand makes the litigation not an alternative to, but a complement to the governance of the climate through legislation and regulation - closing regulatory loopholes, creating normative precedents, sending signals of accountability between and among various levels of the governance structure (Setzer and Vanhala, 2019; Peel and Osofsky, 2020; Sato et al., 2024). According to the unified theoretical model, these four strands reinforce each other: scientific accountability enhances legal accountability; moral accountability enhances governance accountability, and the effects of litigation on governance have a reflective relationship with the normative environment influencing the further use of attribution science and the future use of legal claims.

5.4 Implications to Scholarship and Policy.

The theoretical model adopted has a number of important implications in future academia and policy. To legal scholars it presents an empirical research agenda: are more favourable liability verdicts made by courts which are given a more refined attribution evidence? Are jurisdiction that have a looser standard of causation showing higher success rates of climate litigation? What are the practical implications of the various models of reparative liability compensatory, reparative, transformative (Verheyen and Franke, 2022; Alogna et al., 2021) in various legal jurisdictions? The theoretical model provides the analytical architecture of the global climate justice movement in linking the moral demands of the climate justice movement to the formal legal structures of how accountability may be realized in a practical way. The model forms a theoretical pathway between moral claim and legal remedy by harming the architecture of the loss and damage literature by incorporating the reparative qualities with the precision of attribution of the carbon majors science and the developing duty of care jurisprudence (Grasso and Heede, 2023, Boyd et al., 2021, and Mayer, 2022b). The theoretical model given here is a direction that will have to be empirically tested and perfected as the attribution science keeps developing and judicial faith in the utilization of probabilistic causation evidence increases, which is precisely what this article is aimed at triggering.

6. Conclusion

One serious theoretical lacuna in the current academic literature that has been identified in this article is the lack of a single conceptual framework to bring together the attribution science, legal causation standards, corporate moral responsibility, and climate governance theory into a coherent set of emitter accountability. It postulates that climate attribution science, combined with the development of legal doctrine and corporate responsibility frameworks and governance theory, facilitates the development of a plausible and analytically sound accountability pathway between large industrial emitters and documented climate damage and just claims to amend it.

The article has contributed to the theory in four aspects. First, it has theorised and reported Causal-Legal Accountability Chain - a step-by-step conceptual framework, that shows how the emissions tracing to legal remedy pathway is postulated to be theoretically coherent and scientifically justified at every of its six nodes. Second, it has created a typology of legal obstacles to climate attribution litigation and has shown that all of these obstacles have a theoretically accessible way out based on changing doctrine and advancing scientific understanding. Third, it has speculated the corporate knowledge-deception-liability nexus as the foundation of an enhanced standard of

emitter accountability beyond the normal negligence towards fraudulent concealment and enhancing the moral and the doctrinal case of corporate accountability. Fourth, it has defined the reparative architecture between the science of attribution and the structures of loss and damage, contrasting between the compensatory model of liability and the reparative and transformative models of liability, and their theoretical implications.

There are a number of key theoretical shortcomings recognized in this article. The theoretical framework presented below is based on the already-existing academic literature and has not been supported by any empirical research on case studies or comparative law. There is a conceptual transferral between nodes of the accountability chain, which theoretically is valid, but is in fact the subject of empirical evaluation through the actual behaviour of courts, litigants, and corporations in various jurisdictional settings. The article also has limitations on its scope limited mainly to the English-language literature dealing with common law and European jurisdictions; the theoretical model of the applicability to civil law systems, the jurisdiction of developing countries and non-Western legal systems needs additional analysis. Another aspect of the article is silent on the procedural and resource impediments that costs, time, access to expert witnesses have to the viability of climate attribution litigation, notwithstanding its doctrinal premises.

The theoretical model that is developed in this paper has several agendas that should be pursued in future research. To begin with, propositions of the unified theoretical model should be empirically tested through comparatively larger scale literature on the empirical results of climate litigation in the jurisdictions, on whether the quality of attribution evidence is a predictor of the rates of litigation success. Second, scholarly doctrine must produce more specific criteria of judicial translation of probabilistic attribution into values of liability, on the basis of the new case law analysed in this paper. Third, the international lawism subject matter needs to analyse the means by which the multi-level governance model of climate litigation can be implicated in the formalisation of the binding international instruments that specifically address the responsibility of carbon majors. Fourth, loss and damage scholarship must find operational elements of making distinctions between the three reparative models, compensatory, reparative, and transformative, in both conceptually sound as well as practically feasible by courts and administrative institutions. The potential of the climate attribution litigation as a form of transformation, it is, is ultimately a matter of both the standards of the theoretical frameworks underpinning them and the scholarly community's adherence to the development of the latter. This article is one of the contributions to that community project that is urgent and keeps on going.

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