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Attribution of historical societal impacts and adaptations to climate and extreme events: Integrating quantitative and qualitative perspectives

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In this article, we identify conceptual barriers, particularly regarding causation, that divide quantitative and qualitative research relating past climate and extreme events to historical societal impacts and adaptions, and we propose solutions for better integrated research.

Discussions of societal impacts of climate and extreme events, including conflict and migration, draw on history for comparisons and insights (e.g. Adger et al. 2014). However, relevant historical research has been divided between divergent quantitative and qualitative methods and perspectives, particularly regarding causation.

Quantitative vs. qualitative perspectives

The quantitative studies in this field have come primarily from social scientists working with historical and climate datasets. Employing mainly regression methods such as Granger causality, authors have identified strong statistical associations between climate and weather phenomena and potential societal consequences over past centuries, including conflict and migration (e.g. Pei et al. 2018). Associations are typically made at multidecadal timescales over large regions, but can be at smaller scales if data coverage is adequate. These studies use five principal criteria for causation: (1) historical rationale for the statistical association; (2) strong relationship between the variables; (3) consistency in the relation between the causal variable and effect; (4) timing: the cause must precede the effect; and (5) strong predictive power of the causal variable (Zhang et al. 2011).

Qualitative studies have come primarily from historians, some in the form of monographs (e.g. White 2011), and others as multi-authored articles (e.g. Camenisch et al. 2016). The latter often involve natural scientists but less often social scientists carrying out the quantitative work described above. Most qualitative studies have focused on impacts and adaptation in individual countries and/or periods, drawing on historical and archaeological records in combination with paleoclimate and historical climatology information. Causation is primarily inferred from contemporary attribution, reasoning from actors' motives, identification of underlying causal mechanisms, and historical comparisons (i.e. methods of similarity and difference).

These contrasting approaches have produced mutual criticisms. Reviews by mainly qualitative scholars have faulted quantitative studies for uncritical use of data with uneven temporal and spatial coverage; arbitrary scales of analysis; little consideration of historical and cultural context; and deterministic causal analysis lacking adequate theory (e.g. Degroot 2018; van Bavel et al. 2019). Quantitative scholars have maintained that climate, in conjunction with subsistence pressures, operated as a root cause of impacts at a macro level, leaving room for contingency and agency and for variable triggers and outcomes in individual episodes; therefore, macro quantitative studies reveal valid underlying causal forces absent in micro or qualitative research (Lee 2020).

These criticisms appear representative of issues arising when the "two cultures" of qualitative and quantitative scholarship approach the same topic from different perspectives. Rather than providing conflicting answers to the same questions, they may answer distinct questions using different concepts. By applying up-to-date methodology and philosophy, scholars can find common ground for collaboration (Goertz and Mahoney 2012).

Key insights for integrated research

A first key insight is the pragmatic and contrastive nature of most causal explanation. Contemporary philosophical studies recognize science and humanities explanations as answers to implicit or explicit "why" questions with contrast sets (van Fraassen 1980). These contrasts are typically between units, conditions, or times. Thus, an explanation for the French Revolution of 1789 may take the form of causes for a Revolution *in France* (rather than another political unit) in 1789, a French *Revolution* (rather than peaceful condition) in 1789, or a French Revolution *in 1789* (rather than another time). The context determines the salient contrast, and confusion about the causal question may render an explanation unhelpful or misleading even if factually correct (Ylikoski 2007).

In the case of historical climate attribution, quantitative studies may claim "climate caused conflict", while qualitative studies may examine the same phenomenon and conclude "climate did not cause conflict", and both may be correct within their respective contrast set. For instance, a quantitative study may explain the higher frequency of conflict *during one period rather than another* across many units, but it may *not* explain the presence of conflict *in certain units rather than others* at the same time. By specifying the contrast set in their explanations, both qualitative and quantitative studies can formulate more targeted and defensible claims. Statistical correlation between timing of a climate variable and migration volumes may be formulated as "temporal variations in climate caused temporal variations in migration" rather than "climate caused migration"; moreover, "climate caused conflict" in the quantitative studies should be interpreted as "worse climate caused more conflicts", which correctly matches the explanation in the statistical perspective.

Second, scholars in the field use two distinct approaches to causation: effect-of-cause analysis typical of macro quantitative studies and cause-of-effect analysis usually found in micro qualitative studies and historical monographs. Effect-of-cause analysis identifies statistical relationships between two

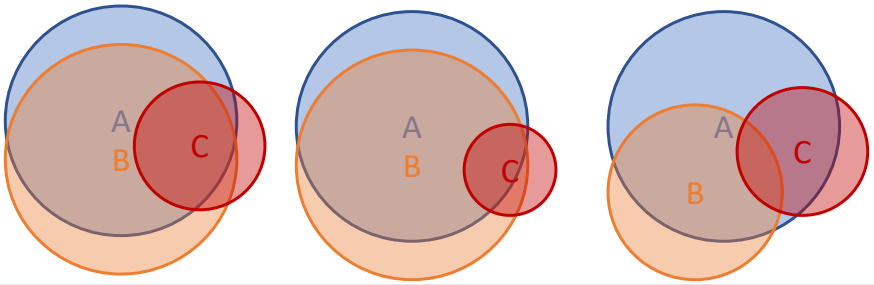

Figure 1: Schema representing frequency and co-occurrence of three INUS for historical famine, where A is vulnerable agriculture, B is inequality, and C extreme weather, and the overlap of all three indicates occurrence of famine. In typical pre-modern conditions (left), occurrence of C overlaps most with the outcome and may therefore be considered "the cause" of famines. Nevertheless, decreasing (increasing) the frequency of any INUS will decrease (increase) the frequency of the outcome (see middle and right). Thus studies concerned with climate impacts may focus on C as the causal variable, while studies concerned with economic policy may focus instead on B.

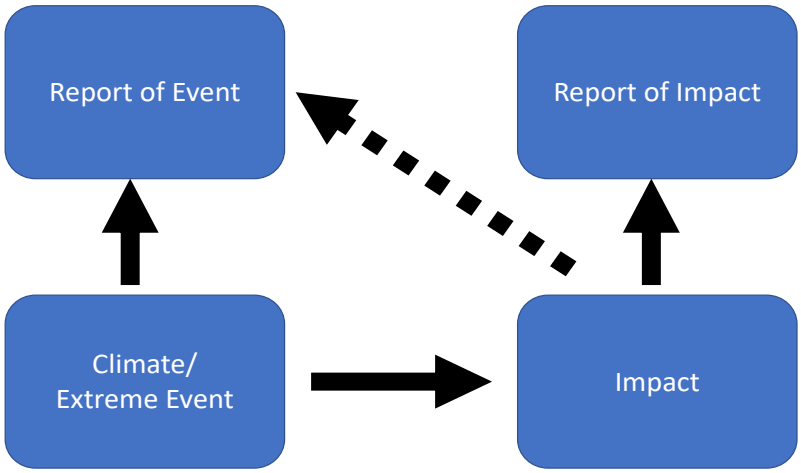

Figure 2: Example of biased reporting. In certain historical circumstances, extreme events were more likely to be reported when they produced impacts (dashed arrow) than when they did not, generating a positive bias in statistical associations.

variables in order to attribute control of one over the other. In historical climate attribution, studies may use regression or potential outcomes analysis to relate a climate or weather variable to the past frequency or magnitude of a quantifiable societal impact, and then interpret this relation in causal terms. Cause-of-effect analysis, on the other hand, identifies logical relationships of necessity and sufficiency – that is, whether some event or condition had to occur for, or was enough to bring about, a particular outcome (Goertz and Mahoney 2012). For historical climate attribution, this approach usually requires inferences derived from historical evidence, comparisons with like cases, and counterfactual reasoning about outcomes if climate had been different.

When quantitative studies identify control of a climate variable over a societal impact, the finding does not imply that climatic factors were necessary or sufficient for each instance of that impact. For example, a study may identify a large-scale statistical relationship between lower temperatures and the frequency of conflict and give this relationship a causal interpretation without implying that climatic change was the cause of any one particular conflict. The process tracing that may accompany such studies is illustrative rather than a complete or deterministic picture of causation in each instance (e.g. Zhang et al. 2011). Conversely, when qualitative studies identify a climatic factor as necessary or sufficient for a historical case of a societal impact, the finding does not imply that the climate variable regularly influenced that type of societal impact. For instance, a study may find that a particular drought was or was not the cause of a single historical migration without concluding that drought frequency or severity influenced migration volumes at larger scales. Thus, these two types of causal analysis are complementary rather than contradictory. When drawing lessons from history, effect-of-cause studies indicate typical past relationships between climate variables and impacts, whereas cause-of-effect studies may indicate causal mechanisms underlying those relationships and the necessary and sufficient conditions for those relationships to persist in the present or return in the future.

A third key insight is that historical outcomes depend on the co-occurrence of insufficient but necessary components of unnecessary but sufficient sets of conditions, or INUS (Mackie 1965). For instance, extreme weather, vulnerable agriculture, and social inequalities did not each cause famines alone, but combined (along with other background conditions) to produce famines on particular occasions. This raises a classic philosophical dilemma: which of these factors should be analyzed as "the cause" of those famines (Hart and Honoré 1985, pp. 36-37)? An intuitive approach is to identify the INUS condition most nearly necessary *and sufficient* for the outcome, as indicated by greatest predictive power over the outcome or occurrence that most nearly overlaps with the outcome (Mahoney et al. 2009). In the case of historical famines described above, the INUS selected as "the cause" will often be extreme weather, because its occurrence predicted the timing of famines better than vulnerable agriculture or inequalities, which were more constant. However, causal selection has unavoidable normative implications (Garfinkel 1981), and studies may emphasize the causation of other INUS conditions due to their policy or ethical relevance (Fig. 1). Historical climate attribution studies may address criticisms of insensitivity to policy or ethical issues by explicitly justifying analysis of climate as "the cause" and specifying the role of other INUS conditions.

These insights clarify when limited datasets are problematic for quantitative impact studies. Contrast set, scale, type of causation, and standard for causal selection determine whether gaps and inconsistencies invalidate causal inferences. In effect-of-cause analyses focused on temporal variations of impacts at large scales, statistically valid results may depend more on wide spatial and temporal coverage than on consistency within that coverage; or else studies may compensate for data inconsistencies by using statistical methods or by expanding the study area and duration. Nevertheless, it remains important that the scale of analysis be grounded first in theory and that the data are suitable for the chosen scale. Systematic biases in evidence can also invalidate causal inferences. In particular, studies based on statistical associations must establish that reporting of climate or weather events and their supposed impacts were truly independent of one another, a determination requiring knowledge of the underlying historical reporting and record-keeping processes (Fig. 2).

These considerations indicate possibilities to overcome conceptual barriers between quantitative and qualitative historical attribution research. Each approach has limitations, which may be partially compensated by better communication across studies and collaboration within studies. Publications could minimize confusion by specifying cause and effect contrast sets, distinct effect-of-cause and cause-of-effect inferences, justification for (not) analyzing climate or extreme events as the key causal variable, and grounds for the scale of analysis. Collaboration may capitalize on the division of labor between qualitative methods of inference from and about historical evidence and quantitative methods of modeling and statistical induction, as well as the complementary functions of effect-of-cause and cause-of-effect analysis, in order to achieve integrated evaluation of historical climate attribution suited to informing policy.

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