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Global Discontinuity: Time for a Paradigm Shift in Global Scenario Analysis

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Abstract: The evolutionary paths of social-ecological systems comprise periods of structural continuity punctuated by moments of convulsive change. Various forms of systemic global shock could materialize in the coming decades, triggered by the climate crisis, social disruption, economic breakdown, financial collapse, nuclear conflict, or pandemics. The unfolding COVID-19 pandemic stands as a real-time example of an interruption of historic continuity. More hopefully, deep institutional and cultural shifts could rapidly usher in more resilient forms of global civilization. These plausible possibilities challenge scenario studies to spotlight discontinuous futures, an imperative that has not been adequately met. Several factors—for example, gradualist theories of change, scientific reticence, the lure of quantitative tractability, embeddedness in policymaking processes—have rendered mainstream scenario analysis ill-suited to the task. The emphasis on continuity fails to alert decision makers and the public to the risks and opportunities latent in our singular historical moment. A shift to a paradigm that foregrounds discontinuity is long overdue, calling for efforts to broaden the base of persons involved; devote more attention to balancing narrative storytelling and a broader range of quantitative methods; and apply and develop methods to explicitly consider discontinuities in global scenario development.

Keywords: scenario development; systems modeling; discontinuity; tipping points; black swans; integrated assessment

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1. Introduction

The choices we make today are influenced by what we imagine, fear, and desire about the future. These choices, in turn, shape the future that ultimately materializes and whether we are able to meet the challenges of sustainability. Coherent thinking about the future is a problem of organized complexity [1], posing profound challenges to both science and the imagination. We can form only cloudy pictures of alternative outcomes and indicative assessments of the effects of our actions. Such imprecision is traced to inherent ontological uncertainty in the dynamics of complex social-ecological systems, epistemological constraints to what we know and can know, and the vagaries of human volition. Thus, it is essential for global future studies to reach beyond "a narrow bandwidth of scenarios that unfold gradually from current patterns and trends" [2].

History shows that social-ecological systems evolve along a path characterized by periods of relative stability punctuated by disruptive episodes of transformation [3–5]. The

key role of surprise and discontinuity (see Box 1) in the evolution of both natural and socio-economic systems is well established [3,4,6,7]. The unfolding COVID-19 pandemic stands as a real-time example of interruption in historic continuity, reminding us of the real risks of confronting other forms of systemic disruption in the coming decades. The potentially disruptive nature of the various manifestations of AI present potential for causes for discontinuities also [8]. Many are concerned about the potential of AI to cause social unrest via misinformation and disinformation propagation [9]. The consequences associated with disruptive discontinuity warrant greater attention as we contemplate and evaluate potential future scenarios.

The risks brought by the increasing interdependence and complexity of the global system has long been noted [10,11]. The rise of populist movements, growth of the internet, acceleration of climate change, and advances in artificial intelligence and genetic engineering have only intensified the turbulence and multiplied the threats [12]. Other significant contributors to emergent instability are rapid urbanization, human migration, economic and financial vulnerability, and geo-political tensions. A recent report by the Club of Rome suggests that disruptions associated with societal collapse will precede and be more significant than environmental collapse(s) [13]. At the same time, countervailing shifts are underway in the culture of production and consumption and the burgeoning search for institutional forms and human values for a transition to a sustainable, equitable, and livable future.

The recognition that these emergent conditions carried long-term, uncertain consequences has brought heightened interest in scenario analysis. With the world facing plausible pathways of systemic disruption, it became imperative that global scenario assessments emphasize discontinuity, but that is a challenge that has not been adequately met. The COVID-19 pandemic brought the idea of disruptive surprises to the forefront, but concern with systemic crisis could easily subside as the crisis fades, as with the "great recession", when many scenario analysts concluded that short-lived events would not significantly influence long-term patterns. Rather than downplaying surprises, shocks, and episodes of systemic reorganization in formulating global scenarios, we now need a paradigm shift that highlights such scenarios.

Adherence to the myth of equilibrium and smooth change [5]—referred to here as the "continuity bias"—constitutes a failure of the scientific imagination. This concern has long been voiced in calls to highlight surprise and discontinuity [14–16]. Scenario assessments that focus on continuity are increasingly untethered from actual conditions and therefore provide a misleading basis for alerting and guiding decision makers and the public. The discontinuity paradigm opens not only conceptual and analytic space for revealing the risks latent in our historical moment, but also ways of shaping a decent global civilization.

We build on the concerns raised by [2] to explore in greater depth the continuity bias and ways to transcend it. Our analysis and conclusions also complement those of [17], who more narrowly explored disruption and discontinuity in energy systems models and scenario studies; Nilsson et al. [18], who focused on environmental and social change in the Arctic; and Keys [19], who called for increased attention to social surprises in scenarios of climate futures. To that end, we first describe the scenario approach and how it has evolved in global social and environmental assessments. We then analyze the reasons for and the consequences of the continuity bias. We close with an exploration of directions for a new paradigm and a concluding statement on the urgency for such a paradigm shift.

Box 1. Note on Nomenclature.

The term "discontinuity is used variously in the scenario literature, broadly signifying a sharp departure from past trends and patterns resulting from high-impact developments, phenomena, and events. The significance of a discontinuity depends on its character, magnitude, speed, and ripple effects, and whether it had been anticipated and ameliorated. As used in this paper, discontinuity refers to a significant shift of social-ecological structure and dynamics, rather than transient perturbations in which the system reverts to its previous trajectory. Related terms are unanticipated 'surprises' [20], 'bifurcation' and 'critical transition' [7], 'tipping points' [6] or 'tipping elements' [21], 'wild cards' [22], and 'Black Swan events' [23]. More recently, the phrase 'game changers' has been introduced for shifts in how society is organized through understandings, values, institutions, and social relationships [24,25].

2. The Scenario Approach

Scenario modeling brings to mind some apocryphal Yogi Berra quotes such as: "It is difficult to make predictions, especially about the future" and "The future ain't what it used to be". Although we cannot predict the future, speculation about human destiny has been ubiquitous across cultures [26]. In the contemporary context, recognition that near-term choices have long-term consequences has brought 'the problem of the future' to the center of scientific and policy agendas [27]. The challenge is to anticipate, plan for, and shape the future in an adaptive process of understanding and action.

The future course of complex social-ecological systems cannot be predicted due to three distinct types of uncertainty: ignorance, surprise, and volition [28]. First, limited knowledge on the current state and dynamics of the system introduces significant epistemological uncertainty, even if the system unfolded deterministically. Second, complex systems are not deterministic: they can exhibit bifurcation, emergence of novel properties, and points of structural reorganization. Third, the trajectory of the future is subject to human choices not yet made in response to conditions not yet manifest.

These profound uncertainties subvert hopes of meaningful scientific prediction of the long-range global future. The scenario approach has evolved as an alternative that invites imagining, envisioning, and analyzing a wide spectrum of possible visions and pathways. Most generally, a scenario is a story about the future that can be told in both words and numbers, offering an internally consistent and plausible explanation of how events might unfold or how an imagined future state might be reached [28,29]. In practice, some scenario exercises have relied heavily on qualitative narrative, some on quantitative modeling, and some on a combination of the two.

By rooting "histories of the future" in an appreciation of what current scientific understanding can and cannot tell us, scenario studies can offer more than mere speculation, while not purporting to predict. At their best, they explore contrasting outcomes that might result from changed assumptions, unconventional developments, and different choices and responses to emergent conditions. This can help guide present-day actions by identifying critical issues, revealing novel risks and opportunities, and highlighting robust responses that are effective across a range of futures [30]. To these ends, scenario exercises need to be clear about their purpose and object of study and transparent about the means by which these were developed. Rich scenario analyses consider multiple incommensurable futures, thereby refraining from assigning mathematical probabilities and enlarging the envelope of possible outcomes.

3. Historical Perspective

The discourse of global scenario studies has included both periods of acknowledgement and dismissal of discontinuity (see Table 1). As properly noted by two anonymous reviewers, our perspective pays little attention to the use of scenarios in the areas such as business and the military, where there is, perhaps, more consideration of surprises and discontinuity as evidenced in [31–33], as well as in discussions surrounding Agile Management and Business Continuity Management. This could be worthy of consideration in a follow-up study. Early contributions depicted scenarios of significant societal

change [34–37], at a time when scenario analysis gained purchase in both public (e.g., [38]) and private [39,40] spheres. The 1980s brought a lull in integrated scenarios as the focus turned to sectoral forecasts of population, energy, agriculture, and other themes. These generally portrayed continuous pathways, perhaps with some variation around a central trend or business-as-usual projection.

Table 1. Overview of main trends in global integrated scenario development.

Period	Illustrative Studies	Description	Level of Integration	Treatment of Discontinuity
1970s	Limits to Growth [35]	First wave of integrated global scenarios	Social and environmental	Significant societal change
Early 1980s	-	Lull	Sectoral analysis	Largely surprise free
Late 1980s	Surprising Futures [16]	Focus on non-conventional scenarios	Integrated, but with sectoral focus	Qualitative consideration
1990s	Global Scenario Group [28,29,41]	Contrasting global scenarios	High	Major surprises and sharp discontinuities
Early-mid 2000s	SRES [42], MA [43], GEO3 [44]. GEO4 [45]	Multiple baselines	High	Include divergence from trends
Late 2000s/early 2010s	GEO5 [46], IAASTD [47]	Discontinuation of development of scenario sets	Reliance on integrated models	Continuity emphasis
2010s	SSP-RCP [48]	New climate change scenarios	Reliance on integrated models	Discontinuity acknowledged, but not implemented in simulations

4. Institutional Challenges

Over time, however, critical reviews of forecasts of population, energy, and agricultural sectors [16,49] noted the absence of surprising futures. As a challenge to the gradualism of many analyses, they described a set of possible surprises. This work reflected the growing scientific recognition of the ubiquity of transformative change in the evolution of complex social and natural systems.

In the 1990s, the Global Scenarios Group (GSG) sprang from rising concerns with long-term sustainability [28,29,41]. An intellectual successor to earlier efforts to take discontinuity seriously, GSG developed three distinct types of scenario streams. 'Conventional Worlds' scenarios exhibit essential structural continuity; 'Barbarization' variants veer toward deeply degraded social structures and environmental processes; and 'Great Transitions' scenarios envision pathways to flourishing forms of civilization. Raskin and Swart [2] revisit GSG's scenario framework to draw insight and lessons for the present. On the other hand, other major efforts in this period, such as the emission scenarios by the Intergovernmental Panel on Climate Change (IPCC) [50,51], remained strictly in Conventional Worlds with simple variations on population, gross domestic product (GDP), technological penetration, and other variables.

In the early 2000s, formal scenario assessments covered more themes and issues and provided more geographic detail. The IPCC's Special Report on Emissions Scenarios (SRES) [42], the Millennium Ecosystem Assessment (MA) [43], and the third and fourth Global Environmental Outlooks (GEO) of the United Nations Environment Programme [44,45] presented an array of scenario narratives, rather than a 'most likely' future. However, rather than analyzing scenarios that exhibit significant change, they focused on smooth paths from the present. SRES [42] (p. 3) explicitly excluded consideration of "outlying", "surprise", or

"disaster" scenarios in the literature. Continuity remained baked into the specifications and algorithms of quantitative models.

For a while, scenario projects were simplified, then, the 2010s saw renewed interest in integrated scenarios, especially in the context of climate change research [48]. The new scenarios, though reflecting some narrative breadth, retained essential continuity in their quantitative simulations. Some urged greater emphasis on discontinuity in the development of the Shared Socioeconomic Pathways (SSPs), the core of the new climate scenarios, including "more rapid than expected technological changes or radical change in political landscapes" [52] (p. 369). Lane and Montgomery [53] (p. 451) raised concerns that "the initial story lines all run on like clockwork through the remainder of this century." In the end, though, these calls went largely unheeded.

This broad-brush historic panorama reveals flirtations with an ontology of discontinuity in scenario studies, but is not a sustained effort to transcend the continuity bias. Only the GSG's scenario set highlights discontinuous restructuring of the global social-ecological system in the twenty-first century. Correspondingly, the GSG typology of scenario archetypes has become a useful framework for mapping elements of other scenario exercises [54–56]. However, almost all scenarios, particularly in their quantification, consider discontinuity weakly, at best remaining neutered versions of the original GSG scenarios.

5. Why the Gap?

Based upon collective experience, we identify four key factors—philosophical orientation, scientific reticence, political embeddedness, and quantitative tractability—that we feel help account for the inadequate attention to disruptive change in scenario assessments. We consider them in turn.

First, the emphasis on continuity may stem from explicit or implicit ontological and epistemological assumptions. Brooks [3] (p. 326) identified a bias toward "an evolutionary paradigm—the gradual, incremental unfolding of the world system in a manner that can be described by surprise-free models," or at least a "hope that in the longer sweep of history surprises and discontinuities will average out, leaving smoother long-term trends that can be identified in retrospect and can provide a basis for reasonable approximations to the future".

Second, the commendable desire to ground scenarios in rigorous science brings with it the culture of scientific reticence. The conservative scientific process abjures the kind of speculative vision and methodological innovation demanded by the challenge of illuminating the long-range future. Van Notten et al. [14] note "the generally negative connotation that the concept of discontinuity has to scenario developers". Although it may be valid in many contexts that extraordinary proof is needed for extraordinary claims [57–59], scenarios are not validated by "proof" in the conventional sense. Rather, they gain purchase through exercise of the informed imagination, qualitative insights, and collective discourse on the kind of world we want. The irony here is that, in the context of scenarios, scientific reticence results in bad science by drawing attention to arguably the least plausible futures of all—essential historical continuity. By contrast, discontinuity needs to be in the core theoretical arsenal of valid scenario science.

A third factor—the pull of political relevance and salience—reinforces philosophical predilections and scientific reticence. Scenario assessments embedded in policymaking processes find their scope constrained by political acceptability and short-term outlooks. National governments have been intimately involved in many assessments. The need for consensus among risk-averse policymakers from diverse countries restricts scenario creativity, even precluding imaginative titles for the IPCC's SRES scenario [60] By contrast, the non-governmental governance structure of the MA permitted more scope. The SSP process has been less formally structured than preceding climate change scenario exercises [52], but the main participants carry forward a disinclination to deeply engage with discontinuity from earlier inter-governmental processes.

The final factor is the lure of mathematical tractability. As [3] points out, this can be traced to "lack of practically usable methodologies to deal with discontinuities and random events". In the vacuum, quantitative models that feature equations and parameters calibrated to the past and persisting into the deep future have become dominant. The overemphasis on such predictive quantification and the seduction of certainty has diverted attention from unpacking the qualitative features of scenario narratives. Indeed, the narratives are often developed by quantitative modelers, including most drafters of the SSP narratives [61] and authors of the paper describing them [62].

Scenario quantifications have relied heavily on so-called Integrated Assessment Models (IAMs), which feature inherently continuous mathematical descriptions. Despite the inability of IAMs to simulate social-ecological transformation, they remain the primary vehicle for understanding system change and informing policies related to these changes [63–66]. This limitation curtails the capacity to represent alternative pathways, including deep cultural and institutional change, for meeting the strong mitigation required by the Paris Agreement. Calibrated to past patterns, these models are blind to structural discontinuity and the spectrum of possibilities for the global future.

6. Consequences

The behavior and decisions of today's actors is influenced by their perceptions of the future [67]. When scenarios present a pinched aperture on the future, the danger is a pinched repertoire of anticipatory changes in behaviors and decisions. These changes include actions that reduce catastrophic risk; e.g., Brysse et al. [59] (p. 335) note that "If climate scientists and assessors are erring on the side of least drama in their predictions, then they are not preparing policymakers and the public for the worst, because they are underpredicting what the worst outcomes might be". This also inhibits insight and action in pursuit of visions of better worlds [35,68,69].

Beyond the policy arena, the continuity bias distorts public awareness and informed mobilization. The broader public can significantly influence policy and, more importantly, cultural and political change. The potential and quality of such engagement is enhanced or inhibited by the quality of prevailing narratives of where we are and where we want to go. When experts present partial pictures of what is plausible or possible, they limit the social imagination and informed engagement to avoid undesirable and seek desirable outcomes [70].

Finally, failing to highlight the essential features of the dynamics of complex social-ecological systems—structural reorganization, thresholds of instability, bifurcation, and emergent properties—also impoverishes scientific understanding. The COVID-19 pandemic, a disruptive future unfolding in real time, makes the importance of historical discontinuity all too clear. Moreover, other destabilizing systemic jolts are visibly maturing or lying latent in social-ecological processes. Going forward, the validity and relevance of scenario assessments will depend on effectively alerting decision makers and the public to the dangers and opportunities for deep change. The current crisis has triggered scenario studies featuring a pandemic, but they will arrive too late to help.

7. Ways Forward

These fraught scientific, policy, and public consequences make clear that the time is long overdue for transcending the continuity bias. We need a paradigmatic shift—a discontinuity in the practice of global scenario analysis itself. The new paradigm would highlight structural shifts, bifurcated pathways, and nonconventional visions of the future. It would foster the development of new methods for the qualitative and quantitative illumination of such futures. It would highlight a rich array of causal factors—human values, power structures, collective action, cultural change—shaping the future, not settling for simple tweaks to population, GDP, and technology.

A renaissance in scenario thinking and methods will be no easy task. Certainly, such reinvention will take a willingness of practitioners to critically reflect on past practices,

acknowledge the challenge, and engage in a sustained discourse on innovative ways forward. There can be no rigid blueprint or plan of action for such an open process. Nevertheless, we can identify a few general guidelines.

First, broaden the base of scenarios developers to include a more diverse mix of disciplines, backgrounds, and points of view. Second, explore new quantitative methods attuned to discontinuity. Third, enhance scenario narratives to amplify critical qualitative features and more discontinuous trajectories. Fourth, explore ways to counter scientific and political reticence that undercuts creative thinking about the future, including perhaps a code of professional ethics. We comment on these directions below.

Previous reviews of scenario processes caution against too narrow a range of participants in scenario development. To generate more informative and useful scenarios, Bennett and Zurek [71] urge integrating epistemologies and incorporating multiple perspectives. Similarly, Wilkinson and Eidinow [72] argue that the 'wicked problem' of global environmental change calls for a reflexive approach that draws from diverse worldviews and types of knowledge. Along different axes, Mach and Field [73] advocate greater interaction between experts and decision makers; Kuhnhenn [74] counsels including more voices from outside the scientific community of the Global North; and others call for reducing the dominance of neoclassical economics with broader social science representation [75–77]. Following Rayner and Malone [78], this would include greater involvement of 'interpretive' social scientists and humanists to bring an analysis of social, cultural, and religious systems to scenario narratives. Recent examples of this can be seen, for example, in the Geoengineering Scenarios project supported by the National Socio-Environmental Synthesis Center (https://codecprs.sesync.org/research/geoengineering-scenarios (accessed on 4 July 2023)) and work coming out of the Center for Science and Imagination at Arizona State University (https://csi.asu.edu/ (accessed on 4 July 2023)).

Regarding methods, Scheele et al. [67] usefully call for an examination of "the particular ontological and epistemological commitments embedded in methodological choices for scenario development". These commitments shape which scenarios are explored and accepted as plausible, tending to privilege predictive over exploratory or normative methods, and model-based over narrative emphasis. These choices influence how scenarios intersect with policymaking processes [79].

To encourage the consideration of discontinuities, we have stressed the importance of a rich narrative with revised quantification methods. This will take a rebalancing to upgrade the role of narratives, a "thick description" [80] approach that devotes more resources to qualitative features of a scenario, and an improved integration between qualitative and quantitative streams [81,82], as suggested in guides for scenario development [30,83,84].

Generating fresh methods for quantitative analysis compatible with scenario discontinuity is an intriguing challenge. A good first step would be the call from Mach and Field [73] (p. 17) for "identifying dimensions missed by the models, such as path dependencies, context-specific determinants, shocks and reversals, and outcomes not economically optimal". Next is acknowledgement of the inadequacy of entrenched conventional models for tracking structural shifts. The tacit assumption is that future states of the system can be reasonably simulated by fixed mathematical relationships among parameters, dependent variables, and gradually changing independent variables.

Such algorithmic continuity is invalid for representing discontinuous system trajectories. These trajectories are better conceptualized as relatively stable "before" and "after" states punctuated by episodes of chaotic reorganization. This framing carries two thorny implications for the next generation of quantification techniques. First, the successor state that emerges from the social-ecological rupture may require a mathematical representation that differs from the precursor state to reflect changes in culture, values, institutions, climate change, and so on. Second, the process of structural reorganization itself is inherently emergent and surprising.

With continuity baked into conventional models, innovative modelling approaches come to the fore. Diniz et al. [85] and Jetter and Kok [86] suggested simulating fundamental

change with fuzzy cognitive models. We would also recommend the consideration of System Dynamics and Agent-Based models, which can better deal with issues of complexity and surprise in formal models. Although much of this work has been sub-global and involved local stakeholders, ways to draw on the experience for global scenario development should be explored.

A general aim is to complexify scenario descriptions and dynamics. The well-known 2×2 matrix approach involving simple variance of one or two key parameters cannot reflect holistic system shifts. Rather, rich conceptual frameworks are needed to represent deeply incompatible future conditions that cannot be expressed as variants of a single baseline. For example, the GSG framework introduced earlier integrates qualitative and quantitative descriptions to articulate deep distinctions between alternative futures.

Another font for innovation is the work testing the robustness of a scenario by introducing wild cards to examine how the scenario changes. For example, Spangenberg et al. [87] introduce shocks (including a pandemic) to demonstrate the limits of linear extrapolation; Hughes et al. [88] examine quantitative impacts of low-probability, high-impact surprises in demographic, economic, and energy patterns; and Pedde et al. [89] linked the SSPs to a set of wild cards, thus injecting disruption into long-term gradual change, including a global pandemic and the collapse of the internet.

Finally, we urge the exploration of new codes of professional ethics in search of a practice that appropriately balances the desiderata of scientific reticence and the voicing of concerns [90]. Given the high stakes, scenario professionals have a duty to inform policymakers and the public about the full range of potential futures. The paradigm shift advanced here can bring to the fore scenarios heretofore sidelined, ranging from tragic collapse to hopeful transformation.

8. Conclusions

Disruptive change is not an anomaly but a prominent characteristic of complex social-ecological systems. As the pace of global change accelerates and the scale of impact expands, transformational and disruptive shifts are omni-present. Climate change is but one manifestation of the anthropogenic capacity to fundamentally alter natural and human systems. COVID-19 and the earlier Great Recession are recent shocks that vividly demonstrate discontinuities. These may be the tip of the iceberg. To wit, we may currently be undergoing a discontinuity from an ice age to a fire age [91] by which people in New York City may be learning through experience the reality of climate change via their difficulty breathing due to smoke from fires throughout Canada.

Nevertheless, global social-ecological scenarios downplay visions of discontinuous shifts, whether to system collapse, an authoritarian world order, or revitalized forms of civilization. The adherence to conventional visions disregards the power of the scenario approach: thinking about novel futures. The dominance of incrementalism in mainstream scenario studies stems from ontological and epistemological biases, the conservative character of scientific and political processes, the lure of mathematical tractability in modelling, and the deference accorded to quantitative over qualitative methods.

The consequences of delimited vision in scenario studies assessments are nontrivial: problematic science, skewed policy advice, and circumscribed public awareness. Scenarios not well tethered to our discontinuity-rife world are quickly rendered moot by unanticipated developments. The time has come to launch vigorous efforts to transcend continuity bias in global scenario studies and develop a new paradigm that spotlights discontinuity.

To facilitate the shift in scenario theory and practice, greater participatory diversity needs to be injected into scenario formulation; greater attention and resources should go to the enrichment of scenario narratives; and methodological innovation is required for quantitative insight on discontinuous scenarios. This process can draw on tools and methods developed in sub-global scenarios exercises where sharp discontinuities and shocks are commonly explored.

Neither the concerns we have raised nor the directions for moving forward are new, but they are increasingly urgent. The failure to foreground discontinuity in an increasingly vulnerable world is reason enough to once again sound the alarm and increase its volume.

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