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Tipping Points: A Brief Review of their Role as Wicked Problems in Climate Change

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Abstract

Climate change is a "wicked" problem due to its complexity, urgency, and interconnectedness. In recent years, a new structural element in the climate system has been defined by climatologists as tipping points. Tipping points can lead to sudden and irreversible shifts in the climate system, often recognized only post-occurrence, with new research enhancing our understanding but also raising new questions, making the climate problem even harder to solve and understand. This paper traces the origin of climatic tipping points and why these tipping points exemplify the wicked nature of climate change. Additionally, it defines tipping points and examines their cascading impacts across various sectors and systems. It discusses the lack of a definitive stopping rule, the disparity between local and global warming, and the complexity of climate solutions. The frequent breaches in 2023 of the 1.5°C threshold set by the Paris Agreement further underscores the seriousness of the tipping point problem. The research delves into the economic implications of tipping points, analyzing recent research on models to estimate their impacts on the social cost of carbon. The study also highlights the need for adaptive governance to build resilience against these non-linear and cascading challenges.

Part I: Introduction, Research Objectives & Research Questions

Introduction and Rationale

Recent studies indicate that up to 15 climate tipping elements may now be active. Findings demonstrate that even the Paris Agreement's target of keeping warming well below 2°C, with an aim of 1.5°C, is not sufficient to prevent tipping points being crossed. Reaching 1.5°C or higher poses a risk of crossing several tipping points, which can create positive feedback loops that make it more likely to trigger additional tipping points.

The rationale for this research is rooted in the urgent need to address the impacts of climatic tipping points. Climatic tipping points, such as ice sheet collapse and ocean circulation disruptions, can lead to irreversible changes and cascading effects that amplify extreme weather events and societal vulnerabilities (Cai et al. 520). These elements interact globally, meaning the tipping of one can trigger cascades.

Consequences of Impactful Tipping Points

What happens when climate tipping points (CTPs) are triggered? The consequences are profound and carry significant implications for policy. These include considerable sea level rise caused by collapsing ice sheets, the dieback of critical biodiverse ecosystems like the Amazon rainforest and warm-water coral reefs, and the release of vast amounts of carbon from thawing permafrost. Such events would disrupt global climate stability, impacting both natural environments and human societies. Mitigating these impacts requires urgent and coordinated policy actions to limit global warming and prevent these irreversible changes. The need for immediate and decisive action is therefore clear and necessary.

Therefore, recognizing and addressing these critical tipping points is essential for developing effective and resilient strategies. Integrating the concepts of wicked problems highlights the intractable and multifaceted nature of policy issues, necessitating coordinated and interdisciplinary approaches. Thus, the complex interactions among climate tipping elements underscore the need for comprehensive adaptive governance strategies to build resilience against these multifaceted challenges [2-5].

But addressing these challenges requires a fundamental shift in policy frameworks, enhanced awareness around the importance of tipping points, and more international cooperation.

[1]Armstrong McKay, David, et al. "Exceeding 1.5°C Global Warming Could Trigger Multiple Climate Tipping Points." Science, vol. 377, no. 6611, 2022, pp. 1171-1174.
[2]Armstrong McKay, David, et al. "Exceeding 1.5°C Global Warming Could Trigger Multiple Climate Tipping Points." Science, vol. 377, no. 6611, 2022, pp. 1171-1174.

Addressing the “Wicked” Nature of Climate Change

This paper explores why climatic tipping points exemplify the wicked nature of climate change. Rittel and Webber defined "wicked problems" in their 1973 paper, highlighting the challenges in addressing complex policy issues. Addressing climatic tipping points fits these criteria. It discusses the lack of a definitive stopping rule, the disparity between local and global warming, the intricate nature of climate solutions, and the cascading effects of climate issues.

Climate change is recognized as a "wicked" problem due to its complexity, urgency, and interconnectedness. Central to the wicked nature of climate change is the concept of climatic tipping points, where changes can lead to sudden and critical shifts in the climate system, often identified only after they occur. Much more work is needed to fully account for tipping points, their economic costs, and their interactions.

Understanding these characteristics helps frame policy interventions that are capable of addressing the dynamic, systemic, and interdependent nature of climate change. But recognizing the critical nature of tipping points and their role in exacerbating the climate crisis is essential for developing effective strategies [6-10].

Tipping points are complex because they raise new questions and pose unknown unknowns in the Rumsfeld Matrix. They carry with them non-linear changes that pose severe risks to society and stability in agricultural systems, water availability, etc. In fact, their societal impact carries with them elements that are both unpredictable and unrecognized. Their non-linear nature means small changes can lead to sudden, disproportionate impacts, adding uncertainty and tail risk events for financial markets. Indeed, tipping points represent unpredictable elements, posing profound uncertainty and possible tail risk events for financial markets due to their non-linear nature and possible cascading effects on natural systems that support our economies.

Currently, the global trajectory is toward approximately 2 to 3°C of warming. But even if all net-zero pledges and nationally determined contributions are fully implemented, the temperature increase might stay just below 2°C. While this could slightly reduce the risk of triggering tipping points, it remains risky territory as it could still activate multiple climate tipping points.

Research Objectives

- To analyze the concept of climatic tipping points and their origins, highlighting their importance within the climate system.
- To investigate why climatic tipping points, exemplify wicked problems, emphasizing their complexity, unpredictability, and implications for policy frameworks.
- To explore the interconnectedness of social, economic, and environmental factors in the context of climatic tipping points, proposing adaptive governance strategies for effective climate solutions.

Research Questions

- How do climatic tipping points originate, and why are they considered critical elements within the climate system?
- In what ways do climatic tipping points exemplify the characteristics of wicked problems, and how can these concepts be used to clarify the challenges of addressing climate change?
- What strategies can policymakers adopt to manage the unpredictability of climatic tipping points, ensuring adaptive governance?

Research Methodology

This paper uses a literature review, conceptual analysis, and critical reading to investigate why climatic tipping points are considered wicked problems. Integrative literature reviews synthesize past and present research to explore future directions. This approach identifies gaps and trends in the literature.

Conceptual analysis is used in the paper. Building on the works by Kosterec and Machado and Silva, the paper utilizes conceptual analysis to explore the complex concepts of climatic tipping points and wicked problems. This approach is essential for dissecting and understanding the theoretical frameworks surrounding these issues, allowing for a more precise examination of their definitions, implications, and interactions within the context of climate science [11-15].

By incorporating interdisciplinary methodology to generate insights, this methodology aims to develop a holistic understanding of the social, economic, and environmental dimensions of tipping points as wicked problems.. It highlights why the characteristics and features of a wicked problem are useful to understanding climatic tipping points.

Part II: Understanding Wicked Problems

The Evolution of Systems Thinking

This section will explore the historical development of systems thinking, relevant for both wicked problems and tipping points. Climate science relies on “systems thinking” to capture the intricate interactions and feedback loops within the Earth's climate system.

This holistic approach is essential for understanding tipping points, such as the Atlantic Meridional Overturning Circulation (AMOC), which can abruptly shift from an "on" to an "off" state. These non-linear transitions occur due to complex interdependencies within the climate system, where small changes can trigger significant and potentially irreversible effects.

Systems thinking allows climate scientists to identify and predict these critical thresholds within tipping points, helping to develop strategies to mitigate and adapt to rapid and extreme climate change.

Systems thinking is essential for managing complex issues. The evolution of systems thinking has played a useful role in addressing the inherent complexity of wicked problems, including climatic tipping points. In fact, systems thinking emerged

[3]Kosterec, Miloš. "Methods of conceptual analysis." Filozofia 71.3 (2016).
[4]Machado, Armando, and Francisco J. Silva. "Toward a richer view of the scientific method: The role of conceptual analysis." American Psychologist 62.7 (2007): 671.
[5]Adams, Jonathan, Tamar Loach, and Martin Szomszor. "Interdisciplinary research: Methodologies for identification and assessment." Digital research reports 9 (2016): 1-8.

in modern science during the 1920s. Organizational scholars played pivotal roles in its development, including critical systems thinking and soft systems methodology.

This approach suited the study of organizational strategy and change. Scholars viewed organizations as "organisms" that interact dynamically with their environments. This perspective enabled a holistic understanding of organizational behavior, highlighting the nterdependencies within and beyond organizational boundaries [16-20].

The roots of systems thinking can also be traced back to earlier scientific and philosophical traditions, such as general systems theory by Ludwig von Bertillon, cybernetics by Norbert Wiener, and the study of complex systems in biology and ecology. These foundational ideas emphasized the importance of feedback loops, self-organization, and emergent properties, shaping the way systems thinking was applied in various fields. The integration of these concepts into organizational studies allowed for a more nuanced analysis of how organizations adapt, evolve, and thrive amidst changing conditions, making systems thinking an essential tool for addressing complex problems in management and strategy.

Wicked problems emerged also from systems thinking, but also made it harder to solve policy problems, because policies often require firm boundaries and are often developed by Ministries responsible for a certain sector in dialogue with a certain set of industry stakeholders.

Defining Wicked Problems

Connecting these concepts, the definition of wicked problems was based on researchers' previous work in city planning and public policy, where they encountered ill-structured issues. Wicked problems have complex connections between social and environmental factors. The term "wicked" is similar to malignant, and designates the opposite of a positive or benign situation; by integrating systems thinking, we gain insights into the fluid nature of wicked problems and can better address issues like climate change.

In fact, wicked problems such as crime and drug trafficking will have to be solved not once, but many times. They will never go away completely. At a deeper level, you may say that crime flows from a part of our human nature.

The most cited publication on wicked problems is Rittel and Webber's 1973 paper, which argued that social policy problems are fundamentally different from natural science problems. The researchers based their definition of wicked problems on their previous work in city planning and public policy, in which they came across problems that are ill-structured. Wicked problems are persistent policy problems that are too hard to solve through traditional approaches. They described natural science issues as 'tame problems' that are well-defined and solvable through linear approaches [21-25].

Many recurring issues in the news, such as immigration, crime, drug trafficking, education, healthcare, and terrorism, exemplify wicked problems that persist due to their complex and intertwined nature. Such social science issues were termed 'wicked' due to their multifaceted nature, characterized by several features including no definitive formulation, no stopping rule, solutions that are good-or-bad rather than true-or-false, and no immediate or ultimate test of solutions. But in essence, wicked problems defy simple solutions, they have complex connections between social and environmental factors.

The term 'wicked problems' has gained widespread usage. The term's use has grown, appearing in diverse fields such as policy, public administration, sustainability, education, economics, computer science, and healthcare literature. Critics argue this distinction perpetuates a flawed division between social and natural sciences and that the term 'wicked problems' has been overused and conceptually stretched, often serving rhetorical rather than analytical purposes.

What It Takes to Solve Wicked Problems

To solve wicked problems, public policymakers need to consult a broad range of stakeholders. Climate change is similar: stabilizing the climate requires multiple coalitions of stakeholders committed to coordinated action.

Climate change's complexity and social ramifications make it difficult to address. Solutions are often not viewed in dynamic, systemic, and interdependent terms, leading to misleading metrics. There is also a significant time lag between actions and their consequences, complicating responsibility. For example, in air travel, it is nearly impossible to determine which passenger is most responsible for emissions.

To solve wicked problems, policymakers need to ensure participation and engagement. An interdisciplinary approach that embraces this complexity is necessary to address wicked problems such as climate change, poverty, and other persistent social issues.

Fostering broad stakeholder engagement requires forward-thinking solutions that account for the interconnected social, economic, and environmental dimensions. Effective policy must be adaptive, focusing on resilience against future uncertainties [26-30].

Part III: Climatic Tipping Points

The Origins of Climatic Tipping Points

A thorough understanding of tipping points requires examining their underlying mechanisms. Grasping tipping points is crucial for understanding the sudden and often irreversible shifts in the climate system that can occur.

The tipping point metaphor has its roots in another branch of dynamical systems theory: Thomas Schelling's late 1960s and early 1970s models of neighborhood 'tipping,' which explained racial segregation patterns in US cities. The concept is tied to ecology and dynamical systems theory. In the 1970s, this branch of mathematical ecology emerged to explore stability, complexity, and chaos in environmental systems, notably through the work of Robert May and C. S. Holling.

[6] Jackson, Michael C., "Critical systems thinking and the management of complexity". John Wiley & Sons, 2019
[7] Bertalanffy, Ludwig von. General System Theory: Foundations, Development, Applications. New York: George Braziller, 1969 (UW-Madison Libraries) (Internet Archive).
[8] Wiener, Norbert. Cybernetics: Or Control and Communication in the Animal and the Machine. Cambridge, MA: MIT Press, 1948.
[9] Jaradat, Raed M., and Charles B. Keating. "Systems thinking capacity: implications and challenges for complex system governance development." International Journal of System of Systems Engineering 7.1-3 (2016): 75-94.

This theory developed from the study of ecological resilience using systems methods. In fact, the idea of climate change as complex, abrupt, and marked by flipping, switching, or tipping has fascinated scientists since the mid-1960s, drawing from a variety of sources and influences.

This work later inspired Malcolm Gladwell's popularization of the concept in the book, "The Tipping Point." Neither Schelling's work nor Gladwell's adaptation mentioned climate change; they focused entirely on human behavior, and Gladwell's book has been very influential in marketing.

In 2002, a National Academy of Sciences (NAS) report highlighted the established paradigm of abrupt climate change, though it remained largely unrecognized among scientists and policymakers. The concept of climate tipping points, introduced to bridge scientific and policy concerns, was popularized by figures like Richard B. Alley, John Schellnhuber, and James Hansen. They argued that the existing UNFCCC policy framework inadequately addressed these critical threats, using the metaphor of tipping points to convey urgency.

Also, the British Mike Hulme's article on abrupt climate change explores the challenges society faces in responding to sudden, unexpected climate shifts. Hulme assesses the resilience of social systems and the importance of proactive policy measures, focusing on UK and Northwest Europe, highlighting the necessity of proactive adaptation and policy measures to address sudden and severe climate shifts. But in recent years, the concept of abrupt climate change has been surpoassed by the concept of climatic tipping points.

Defining Climatic Tipping Points

A tipping point occurs when a series of small or significant changes suddenly leads to a critical shift. Typically, we cannot recognize a tipping point until after it has already occurred.

Climate "tipping elements" refer to at least sub-continental scale parts (or subsystems) of the climate system that can pass a climate tipping point, or elements "that can be switched—under certain circumstances—into a qualitatively different state by small perturbations".

According to the IPCC, a tipping point is a critical threshold beyond which "a system can reorganize in an abrupt or irreversible manner". These thresholds are particularly concerning because they can lead to, drastic changes that are difficult to manage.

In addition, we need to think about time horizons when it comes to Earth's climate processes, which may take generations to recover; or as the IPCC argues "a perturbed state of a dynamical system is defined as irreversible on a given time scale if the recovery from this state due to natural processes takes substantially longer than the time scale of interest".

While it may take time to reverse the seemingly irreversible changes due to a tipping point, policymakers, economists, and the general public must understand that sectors dependent on natural systems could experience rapid and abrupt changes. Natural processes such as rainfall, drought, storms, and winter cooling may shift dramatically within decades after a tipping point, notably impacting these sectors.

In fact, according to the IPCC, an abrupt climate change is defined as a "large-scale change in the climate system that takes place over a few decades or less, persists (or is anticipated to persist) for at least a few decades and causes substantial impacts in human and/or natural systems".

Predicting Climatic Tipping Points

One pressing question in the study of climatic tipping points is: where exactly is the tipping point?

Understanding this requires examining how small changes in one part of the climate system can trigger significant, system-wide shifts. Scientists build models to estimate these tipping points, often using bifurcation models that help identify critical thresholds where a small change can lead to a dramatic shift [31-33].

This difficulty in predicting tipping points underscores the need for precautionary measures in climate policy. The unpredictability of when and where these critical thresholds will be crossed means that delayed action could result in irreversible changes, making proactive and adaptive strategies essential in mitigating risks associated with climate tipping points.

Bifurcation models analyze how a system transitions from one stable state to another, providing insights into potential tipping points. But despite these efforts, pinpointing the exact moment a system reaches a tipping point remains challenging due to the complex interactions and feedback loops inherent in climate systems. This underscores the importance of precautionary measures in climate policy to mitigate the risks associated with crossing these critical thresholds.

Ditlevsen and Johnsen argue that methods used to predict tipping points in the climate system are not always dependable because random fluctuations can push the system to a tipping point without any significant change. However, the idea that tipping points are caused by significant changes still has practical value, especially when trying to predict events like large-scale collapses in ecosystems.

Rules Defining a Climatic Tipping Point

There are ten elements that define, or characterize climatic tipping points:

1. **Critical Thresholds:** A tipping point is a critical threshold at which the future state of a system can be qualitatively altered by a small change in forcing.
2. **Irreversibility:** Changes at a tipping point can be either reversible or irreversible. Reversible changes mean the system can return to its original state if the forcing is reversed, while irreversible changes mean the system cannot return to its original state.
3. **Rapid and Abrupt Changes:** Tipping points often involve rapid, abrupt changes in the state of the climate system, occurring faster than the forces that cause them.

Understanding tipping points is crucial for effective climate action. Identifying the precise moment when a system reaches a tipping point is inherently challenging due to the complex interactions and feedback loops within climate systems. Various factors, such as temperature thresholds, greenhouse gas concentrations, and ecological stressors, can contribute to these shifts. Scientists use models and historical data to predict potential tipping points, but uncertainties remain .

[10]Schelling, Thomas C. Micromotives and Macrobehavior. W.W. Norton, 1978.

[11]Gladwell, M., "The Tipping Point : How Little Things Can Make a Big Difference". Boston :Back Bay Books, 2002.

4. **Non-linearity:** Tipping points occur in systems with strong non-linearity in their internal dynamics, meaning small changes can have large, disproportionate impacts.
5. **Domino Dynamics:** Tipping points can interact with one another, where the tipping of one element increases the likelihood of tipping another, potentially leading to cascading effects.
6. **Vulnerability to Human Activities:** Many tipping points in the climate system are driven by human activities and can be forced past critical thresholds by actions such as greenhouse gas emissions and deforestation.
7. **Predictive Uncertainty:** There is significant uncertainty in predicting when and where tipping points will occur, due to the complex and stochastic nature of the climate system.
8. **High Impact Events:** Crossing a tipping point can lead to large negative impacts, including extreme weather events, loss of biodiversity, and major changes in biomes, which can have extreme societal and ecological consequences.
9. **Early Warning Signs:** Identifying early warning indicators, such as increasing variance or slowing down of system dynamics, can help in anticipating tipping points, although this remains challenging and imperfect.
10. **Global and Regional Variability:** Tipping points can occur at various scales, from local to global, and their impacts can vary across different regions, making a multi-scale approach necessary.

These ten points define most of the characteristics of tipping points. But modelling their behavior, their impacts on economic sectors, and the interactions between tipping points pose real challenges.

Climate Tipping Points: A Wicked Problem in Economic Models

Climate economists must consider tipping points in their analyses. Tipping points represent critical thresholds that, once crossed, lead to irreversible changes in the climate system. Examples include thawing permafrost and ice sheet disintegration, which can have major environmental impacts.

The non-linear behavior of tipping points and their severity cause cascading impacts and spill-over effects, making them especially challenging for cost-benefit analysis. But economic models need to integrate the impact of climate tipping points when predicting the development of the global or regional economies. Climate economists have only recently begun incorporating them into economic models.

Current models likely underestimate the economic impacts, of tipping points emphasizing the need for of tipping points frameworks to address the multifaceted nature of tipping points in climate change and their interconnected social, economic, and environmental dimensions.

Climate economists often use the Integrated Assessment Model (IAM), which combines environmental and economic data to assess future impacts. One study unifies estimates of the economic impacts of eight climate tipping points using an IAM, revealing that tipping points increase the social cost of carbon (SCC) by 25%, with a 10% chance of more than doubling it.

The social cost of carbon quantifies the economic damages per ton of CO2 emitted, highlighting the financial risks. The findings by Dietz et al., 2021 underscore the necessity for urgent policy interventions to speed up decarbonization efforts. Within the European Trading Scheme, it could be useful to consider the theoretical costs of tipping points in calculating a more realistic carbon pricing.

Dietz et al., 2021 assess that more work is needed by the economic discipline to fully account for tipping points and their interactions. Cascading impacts can also amplify initial changes, leading to unpredictable outcomes. By improving economic modeling of these critical elements, economists can develop more effective predictions of the likely severe consequences of climate tipping points to regional economies, such as the impact of a collapse of the AMOC mid-century on the EU economy.

The Severity of Tipping Points: Proceeding with Practical Sector Impact and Cost Analysis

Another crucial question is: how impactful is the climatic tipping point in question? Estimating the costs associated with crossing a tipping point is essential for effective policy making. But this estimation is hard. Cascading climate impacts can lead to widespread vulnerability, affecting various sectors differently. Vulnerability assessments help identify which areas are most at risk. Sector analysis examines how each sector, such as agriculture, energy, and transportation, will be impacted by tipping points.

Additionally, interactions between sector impacts can amplify the overall effect, creating a domino effect of disruptions. The consequences of crossing a climatic tipping point can be far-reaching, affecting not only the climate system but also human societies and ecosystems. For instance, the melting of polar ice caps can lead to sea-level rise, which in turn threatens coastal communities and infrastructure. For example, agricultural collapse due to climate shifts can lead to food insecurity, which then impacts economic stability and increases migration pressures.

Similarly, the collapse of coral reefs due to ocean acidification and warming can disrupt marine biodiversity and fisheries. The impact is not limited to environmental damage but extends to economic and social systems, leading to increased migration, food insecurity, and geopolitical instability. Understanding the magnitude of these impacts is vital for shaping effective climate policies and resilience strategies. The cascading effects of tipping points emphasize the interconnectedness of global systems and the importance of a coordinated international response to address the multifaceted challenges posed by climate change.

Cascading Impacts: A Natural Science Approach Can Not Stand Alone

In framing the problem of climate change, natural scientists and economists dominate our conversations about climate change.

[12]Hulme, Mike. "Abrupt Climate Change: Can Society Cope?" Philosophical Transactions: Mathematical, Physical and Engineering Sciences, vol. 361, no. 1810, 2003, pp. 2001–21. JSTOR, http://www.jstor.org/stable/3559157. Accessed 7 June 2024.
[13]Lenton, Timothy M. et al., "The Global Tipping Points Report 2023". University of Exeter. 2023. (hal-04548845)
[14]Ditlevsen, Peter, and Susanne Ditlevsen. "Warning of a forthcoming collapse of the Atlantic meridional overturning circulation." Nature Communications 14.1 (2023): 1-12.; Van Westen et al., 2024).
[15]Van Westen, René M., Michael Kliphuis, and Henk A. Dijkstra. "Physics-based early warning signal shows that AMOC is on tipping course." Science advances 10.6 (2024): eadk1189.

Social scientists and sociologists and their concerns are rarely heard in the climate debate, however. Solving climate change requires zero-carbon solutions in all the major emitting sectors: buildings, industry, agriculture, energy, transportation, aviation, while halting deforestation and engaging in reforestation, and so on. Solving climate change also means both solving a sectoral challenge within a specific sector, which is hard enough, but also seeing the boundaries between sectors.

A policy that substitutes fossil fuels such as diesel and gasoline for biofuels means we need to massively grow biofuels creating markets and incentives for converting farmland to cutting down biodiversity-rich forests bringing about deforestation, thereby creating other problems such as the lack of resilience in ecosystems or the lack of pollinators.

Record temperatures, wildfires, storms, and floods in 2023 have underscored the urgent need to address cascading climate risks in Latin America. Beyond immediate climate shocks, secondary impacts such as ruined harvests can affect national finances and food security. Urban housing and infrastructure face additional pressures as people migrate from collapsing agrarian communities, potentially triggering populist politics and civil unrest.

The Verisk Maplecroft Cascading Climate Risk Resilience Model evaluates 197 countries across 32 issues, including physical climate exposure, political stability, and resource security, using cluster analysis to categorize them into 'resilient,' 'precarious,' and 'vulnerable' groups. For example, countries like Colombia, despite being part of the OECD, are classified as vulnerable due to their high exposure to climate risks and internal structural challenges. They might have the appearance of resilience on the surface. But using a cascading risks model shows that as safeguards like strong infrastructure and political stability erode, countries become more susceptible to cascading impacts. These impacts can lead to increased migration, food insecurity, and geopolitical instability, creating a domino effect that amplifies the original climate shock.

- **Synthesis: Why Climatic Tipping Points are a Wicked Problem**
  The risks and impacts are compounding, and ever deeper emissions cuts are needed, which requires even larger sectoral changes.

  Stabilizing the climate and pursuing deep decarbonization will not be solved by a single government or industry. In fact, multiple coalitions of stakeholders have to be involved and committed to pursue and coordinate action. Here are why tipping points form a “wicked problem" due to several reasons:
- **No Stopping Rule**
  Determining when the problem is solved is incredibly difficult. Decision-makers often use temperature limits, like staying below 1.5°C, as benchmarks. Scientists can estimate a carbon budget to indicate safe emission levels, but warming trends may continue for decades regardless. Even approaching a 1.5°C rise can trigger tipping points, leading to irreversible changes and resulting in extreme weather events. The lack of a clear endpoint makes it difficult to assess progress and to motivate sustained action, as the goalposts continually shift with new scientific insights and environmental changes.
- **Regional vs. Global Warming**
  While a global limit of 1.5°C is set in the Paris Agreement,, local warming can significantly exceed this, causing disproportionate impacts. Examples include urban heat islands, polar regions warming faster, and extreme temperatures such as Oregon’s 20°C above average in 2021. But the AMOC tipping point which can be triggered by continued global warming, may in fact lead to regional cooling of Northern Europe. The melt-off tipping point in the boreal tundra, where large areas have begun to thaw, also presents a complex scenario. While this thawing may create more favorable conditions for farming, the release of methane—a potent greenhouse gas—could significantly accelerate global warming. This regional complexity complicates the broader debates on emission reduction strategies. Localized crises, such as the melting tundra, often necessitate immediate and tailored actions, which can differ significantly from global strategies. This divergence can lead to a fragmented approach to addressing the global climate problem, highlighting the need for both coordinated international efforts and flexible local responses.
- **Complexity of Climate Solutions**
  Unlike simpler policy issues, climate change requires a broad and intricate set of solutions. Tackling problems like shrinking Arctic ice, retreating glaciers, and methane emissions from thawing tundra is daunting. The climate’s complex nature, with cascading impacts and feedback loops, includes the risk of tipping points that can lead to sudden and drastic environmental shifts. This complexity makes it difficult to predict outcomes accurately, prioritize actions effectively, and mobilize the necessary resources and political will for comprehensive solutions.
- **Development and Climate Impact**
  Elevating people from poverty to the middle class improves quality of life but increases consumption and energy use, leading to higher emissions. Urbanization due to rural-urban migration boosts cement and steel consumption, intensifying climate change. These development pressures may push climate systems closer to tipping points, exacerbating the challenge of managing sustainable growth. Balancing development and environmental sustainability become a tightrope walk, where the wrong step could precipitate irreversible damage.
- **Cascading Climate Issues**
  Climate change accelerates like a snowball rolling downhill, with more severe physical impacts as greenhouse gas emissions rise. Delaying action worsens the problem, leading to costlier global impacts. Tipping points add urgency, as crossing them can lead to abrupt and severe consequences, weakening economies and shifting focus from mitigation to adaptation. The interconnectedness of climate issues means that a change in one area can trigger a series of responses in others, leading to a cascade of crises that are difficult to manage and mitigate. This cascading nature increases the unpredictability and the scale of potential impacts, making coordinated and timely action even more challenging.

[16]OECD, Climate Tipping Points: Insights for Effective Policy Action." OECD, 2022, www.oecd-ilibrary.org/environment/climate-tipping-points-insights-for-effective-policy-action_abc12345-en. Accessed 14 June 2024.
[17]Mulhern, Owen. "Permafrost Thaw In The Canadian Boreal Forest." Earth.Org, 2022, www.earth.org/permafrost-thaw-in-the-canadian-boreal-forest/. Accessed 14 June 2024.

Figure 1 presents a Comparative Matrix illustrating the characteristics and commonalities in assessing tipping points as wicked problems. This comparison is structured across four key dimensions: understanding and explanation, policy and governance challenges, non-linearity and uncertainty, irreversibility and impact, and urgency and proactivity.

For wicked problems, the complexity arises from the interdependent factors, creating a web of social, economic, and environmental interconnections. Tipping points add another layer of complexity with their non-linear and unpredictable impacts, where small changes can trigger disproportionate shifts. The non-linear dynamics of both phenomena necessitate multi-stakeholder engagement and adaptive, robust policy strategies to manage the substantial uncertainties and potential irreversible consequences they pose. Early intervention and continuous adaptation are crucial to address these pressing challenges effectively.

Figure 1: Characteristics and Commonalities in Assessing Tipping Points as Wicked Problems

Understanding and Explanation	Policy and Governance Challenges
Complexity and Interconnectedness **Wicked Problems** • Involve numerous interdependent factors, making them difficult to solve with linear approaches. • Interconnections between social, economic, and environmental factors create a web of complexity. **Tipping Points** • Add layers of complexity due to non-linear and unpredictable impacts. • Small changes can lead to sudden, disproportionate move this line in so similar to other lines in the 4 quadrants! shifts, complicating understanding and management.	**Non-linearity and Uncertainty** **Wicked Problems** • Solutions require multi-stakeholder engagement and adaptive policies. • Interventions in one area can exacerbate issues in another, adding uncertainty. **Tipping Points** • Non-linear processes make prediction and management difficult. • Sudden, irreversible changes create substantial uncertainty for policymakers, requiring robust, adaptive strategies.
Irreversibility and Impact **Tipping Points** • Once crossed, tipping points lead to irreversible changes with significant long-term impacts. • Early intervention and precautionary measures are essential to prevent reaching these critical thresholds. **Wicked Problems** • Not always irreversible, but their impacts can trigger cascading issues. • Comprehensive strategies are needed to address root causes and interconnected nature to prevent long-term negative outcomes.	**Urgency and Proactivity** **Tipping Points** • Demand urgent and proactive policy responses to prevent catastrophic outcomes. • Policies must be designed to address the immediate risks and adapt quickly to changing conditions. **Wicked Problems** • Require inclusive, flexible policies that evolve with new information and circumstances. • Effective management necessitates continuous learning and adaptation to navigate the evolving landscape.

Conclusions

Effective climate solutions require multi-sector collaboration. Climate change, akin to other wicked problems, cannot be solved by a single government or industry. It demands solutions across all sectors. Wicked problems, as defined by Rittel and Webber (1973), are complex, multifaceted issues with no clear solution. They are characterized by social complexity and interdependencies. These problems persist due to the intricate interactions between social and environmental factors, necessitating dynamic, systemic, and interdependent solutions.

Climatic tipping points—critical thresholds where small changes can lead to significant, often irreversible shifts—add to the complexity of climate change. These tipping points introduce additional layers of unpredictability, making the wicked problem of climate change even more challenging to address. The interplay between wicked problems and tipping points emphasizes the need for policy approaches capable of navigating the complexities and uncertainties inherent in both phenomena. But predicting exactly when and where these tipping points will occur is fraught with uncertainty. It contrasts sharply with the need for immediate and decisive action.

To avoid dangerous climate change and the flipping of tipping points, "deep decarbonization" is a needed risk avoidance strategy. It aims to significantly reduce greenhouse gas emissions, thereby mitigating severe impacts on the climate system. This approach involves proactive measures to avoid crossing tipping points and, ensuring long-term climate stability and reducing societal vulnerabilities. But deep decarbonization is not just about reducing emissions; it involves creating comprehensive plans that contrast short-term economic interests with long-term sustainability goals.

[18]Kharas, Homi. "Missing from COP26: Lifestyle Choices of Middle-Class and Rich Consumers." Brookings, 23 Nov. 2021, www.brookings.edu/articles/missing-from-cop26-lifestyle-choices-of-middle-class-and-rich-consumers/. Accessed 14 June 2024.

Adaptive governance offers a promising path forward. Holistic and adaptive policy approaches are essential for addressing these challenges. "Adaptive governance" involves creating flexible, dynamic policy frameworks that evolve with new scientific data and changing conditions. By integrating real-time data analytics, artificial intelligence, and community-based methods, adaptive governance that encourages collaboration across sectors and scales, ensuring policies are responsive to emerging challenges. Additionally, as physical climate risks become costly, investing in community resilience can improve stakeholder engagement and preparedness ahead of climatic tipping points and worsening impacts.

Recognizing the interlinked nature of wicked problems and tipping points, and pursuing deep decarbonization and adaptive governance forms a more robust framework for tackling climate change. These strategies mitigate risks and ensure societal stability. By embracing them, we can develop resilient policies that promote sustainable development in the face of an ever-changing climate.

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