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The Continuing Case for a Polycentric Approach for Coping with Climate Change

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Abstract: Elinor Ostrom argued that effectively coping with manmade climate change requires a polycentric approach. Although we agree with Ostrom's assessment, her arguments regarding the advantages of polycentricity could be taken further. In this paper, we supplement Ostrom's work by fleshing out the reasons of how and why a polycentric approach is more conducive to coping with climate change than national governments that attempt to centrally direct climate change policies. We argue that there are at least six advantages that polycentric systems have for coping with climate change: competition among decision makers, cooperation among decision makers, perceptions of legitimacy that lead to coproduction, mutual learning through experimentation, institutional resilience/robustness, and emergent outcomes that are socially desirable but not centrally planned. The combination of these six factors gives polycentric governance systems distinct advantages over more top-down ones, especially in terms of epistemics and incentive compatibility. Scholars and policymakers who are concerned about the implications of climate change should appreciate the many diverse and nuanced advantages of a polycentric approach for coping with climate change.

Keywords: polycentricity; climate change; collective action problem; public policy; Elinor Ostrom



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1. Introduction

Across the globe, human-caused climate change is adversely impacting a variety of social and natural systems [1]. Scholars, policymakers, and activists continue to debate the most effective ways for societies to mitigate climate change and adapt to its effects. Nobel laureate Elinor Ostrom recognized human-caused climate change as a major collective action problem. Three classic social dilemmas, negative externalities, public goods provision, and free riding form the core of the climate change issue. Drawing on decades of her theoretical and empirical research, Ostrom [2] argued that the most effective way for societies to mitigate and adapt to complex collective action problems such as climate change is a polycentric approach with multiple decision-making centers, which overlap and are nested within one another. Ostrom argued that governments, markets, and civil society are most effective when they tackle this social dilemma at multiple scales and levels. Treating climate change with a one-size-fits-all, top-down approach would likely result in multiple shortcomings, including epistemic limitations, incentive incompatibilities, and a lack of perceived legitimacy by those who are governed.

We agree with Ostrom's core assertion that a polycentric approach is the best means to cope with climate change, but her 2014 paper does not go far enough in explaining why true polycentric approaches are superior. Other scholars extend Ostrom's arguments by applying the logic of polycentricity to climate change in a variety of ways [3–15]. Additionally, scholars use the logic of polycentric systems to understand other complex collective action problems, including healthcare, public safety, and resource management [16–25]. We build on this foundation and synthesize these scholars' arguments to take the logic of polycentricity to its fullest conclusions. This paper fills a gap in the literature by explicitly laying out why and how polycentric systems are best equipped to address climate change,

especially at the meta-level of governance, which includes the interactions of governments, markets, and civil society.

We identify six advantages of polycentric systems for coping with climate change. First, polycentric systems foster competition among various decision makers, which constrains the abuse of decision-making power and provides incentives for an increased responsiveness to constituents' or consumers' demands. Second, polycentric systems allow for cooperation among various decision makers, which facilitates collaboration between different entities in order to develop institutional solutions that match the scale of the problems and conform to local preferences. Third, polycentric systems decentralize many decisions to lower levels, which likely increases local legitimacy because decisions are made by local representatives, not far-removed ones. When individuals see rules as legitimate, they are more likely to participate in the coproduction of monitoring and enforcement, increasing the likelihood that collective action will be successful. Fourth, the existence of multiple decision makers allows them to try out a variety of approaches, which facilitates experimentation and mutual learning. Fifth, polycentric systems are more institutionally resilient and robust than monocentric systems because failures only affect a part of the system, not the entire thing. Sixth, polycentric systems allow for emergent properties in which smaller-scale actions aggregate into large-scale outcomes that are socially desirable but not centrally planned.

In short, our theoretical argument is that a polycentric approach can provide for more contestation and cooperation among decision makers, which gives greater capacity for decentralization and innovation, including smaller-scale solutions that can be scaled up and greater institutional resilience. Our argument is mainly theoretical, but we aim to elucidate that theoretical argument by discussing the US's polycentric climate change approach over the past few decades. The various overlapping government entities, market firms, and nonprofit organizations in the US provide an illustrative example of a polycentric approach to coping with climate change.

The main implication of our research is that scholars and policymakers who are concerned about the negative effects of climate change should appreciate the many diverse and nuanced advantages of a polycentric approach. In particular, the six advantages listed above are especially important in terms of epistemics and incentive compatibility. Knowledge problems and incentive problems abound in the policymaking process; the features of competition, cooperation, and contestation in polycentric systems mitigate those problems. Some degree of decentralization allows experimentation, mutual learning, and cooperation, which in turn allows governance systems to gain access to the dispersed, local, tacit, and inarticulate knowledge that is necessary to overcome difficult collective action problems. Competition and contestation also provide checks, balances, and backstops to individuals in positions of power, which provide those individuals with incentives that are better aligned to address complex social dilemmas. Thus, formal *government* is not the only source of *governance*. The interactions of various levels of government, markets, and civil society constitute a meta-polycentric order that may provide the knowledge and incentives necessary to cope with climate change.

It is important to note that all international-level policies are inherently polycentric because there is no world government, meaning that the international community of sovereign countries has always constituted a polycentric order. However, at the national and subnational levels, governance systems can be more or less polycentric. If national governments dominate decision-making processes regarding climate change policies, then overall governance will be more monocentric, even if it is not perfectly monocentric. National governments can facilitate a polycentric approach if they allow some degree of decentralization in the policymaking process as well as giving markets and civil society a relatively large degree of autonomy. Thus, Ostrom implicitly and explicitly argued for a meta-polycentric approach in which power and decision making is divided among various levels of governments, markets, and civil society.

This paper proceeds as follows. In Section 2, we survey the literature on polycentricity to define and contextualize it, and we review how Ostrom and others have tied polycentricity to climate change. In Section 3, we describe six advantages that polycentric systems have over monocentric systems. In Section 4, we tie those six advantages to coping with climate change as a social dilemma. Then, we use a brief case study of the United States to illustrate how a polycentric approach functions in the real world. In Section 5, we conclude with the implications of this research.

2. Polycentricity, Its Theoretical Development, and Application to Climate Change

2.1. Defining and Contextualizing Polycentricity

The concept of polycentricity was developed independently by Michael Polanyi [26] and V. Ostrom, Tiebout, and Warren [27]. Over the next few decades, scholars would articulate the concept of polycentric governance more clearly and describe its social functions and advantages. Vincent and Elinor Ostrom were instrumental in developing the theory of polycentricity and providing empirical evidence of it in practice. The Ostroms and their colleagues examined polycentric systems in a variety of contexts, including municipal consolidation, groundwater governance, policing, and common-pool resource governance, among many other examples [27–36].

Polycentric systems are those with multiple decision-making centers that are both overlapping and nested; no one center of power dominates the others [37,38]. The existence of multiple decision-making centers means that competition, cooperation, and contestation are all simultaneous characteristics of a polycentric system. Purely monocentric systems lack competition, cooperation, and contestation because there is only one decision maker, leaving no one else to compete against or cooperate with. In reality, most systems are on a spectrum of more to less polycentric. Pure monocentric systems are rare in the real world because decision-making power is not easily centralized.

There are many examples of polycentric systems. Federalist systems of government are polycentric because decision-making power is divided vertically (among the national, state, county, and city governments) and horizontally (among legislative, executive, and judicial branches). Other entities are also polycentric, such as markets, the scientific community, and civil society more broadly.

Government, markets, and civil society are each internally polycentric; however, a meta-polycentric governance structure exists in which government, markets, and civil society overlap. The smaller entities within governments, markets, and civil society may compete against, cooperate with, or contest one another. There are many examples of this meta-polycentric arrangement. A civic association may cooperate with a city government in a public–private partnership. Two market firms may choose between a public court or a private adjudicator to resolve a dispute. Nonprofit groups may organize protests against government policies or firm practices that they find morally wrong.

Polycentricity is not synonymous with decentralization, especially as it relates to government. Of course, polycentric systems will have a large degree of decentralization in many respects, but some decisions will be made in larger communities. Government entities at the city, county, state, and national levels make public policies simultaneously. Some policies will be most effective at the lowest level, but others are more optimally carried out at the regional, state, or federal level. The primary concern of deciding which level(s) to use is the nature and scale of the issue to be addressed. Polycentric systems allow the scale and scope of governance to match the scale and scope of a problem. Complex social problems often necessitate many overlapping policies to find workable solutions. For example, providing a society with energy is a complex problem that is addressed through the polycentric order of government policies, market decisions, and civil society actions.

How socially beneficial polycentricity will be depends in part on the system’s institutional details. Polycentric systems generally involve some degree of competition, but the institutional details of each determines whether competition manifests as a “race to the top” or a “race to the bottom.” The institutional details shape whether cooperation will be so-

cially harmful as collusion or socially beneficial as collaboration, and whether contestation will lead to violent conflict or checks and balances. Elinor and Vincent Ostrom's decades of work on polycentricity is intimately tied to the research on the study of institutions and institutional design. Polycentricity is not a panacea to solve collective action problems; polycentricity will only help solve such problems when the institutional details set up an incentive structure and epistemic structure that channel competition, cooperation, and contestation in socially productive ways [30–32,37–42].

2.2. Elinor Ostrom and Others on Polycentric Approaches to Climate Change

In “A Polycentric Approach for Coping with Climate Change”, Ostrom [2] p. 98 argues that “waiting for a single worldwide ‘solution’ to emerge from global negotiations” is not likely to address the time-sensitive nature of mitigating greenhouse gas emissions. Since political debates about fairness, justice, efficiency, enforceability, and costs continue to rage between leaders of various countries, a global consensus over particular policies or approaches is unlikely to arise in the near future, if ever. The processes of mitigation and adaptation related to climate change require substantial changes to the “day-to-day activities of individuals, families, firms, communities, and governments at multiple levels—particularly those in the more developed world” [2] p. 99.

As Ostrom argues, climate change is an especially difficult problem to address because it combines several social dilemmas at the largest scales, i.e., the national and international levels. At its core, the problem of climate change policy making is a classic public-goods problem and a free-rider problem. The benefits of reducing emissions applies to everyone, regardless of whether they bear any of the costs. Each individual has an economic incentive to let other people pay the costs while personally reaping the benefits. In this case, as with many other social dilemmas, individual rational self-interest can stand at odds with the socially desirable outcomes of the group to which the individual belongs. Some individuals may choose to cooperate, but it is likely that many more will choose to free-ride, thus undermining the coordination required to achieve the desired social outcome [2] p. 101.

Much of Elinor Ostrom's research shows that real-world evidence often contradicts what pure theory concludes. Since humans are creative, they can and do find ways to overcome the free-riding problem by developing self-organized institutions that align incentives for cooperation and provide mechanisms for the monitoring and enforcement of those institutions, especially at small to medium scales [2] p. 103. Even if a formal government creates a policy to overcome an externality or a free-rider problem, citizens still need to cooperate, and government agents must have workable forms of monitoring and enforcement to induce citizens to comply. Preference heterogeneity complicates systems of monitoring and enforcement because individuals have different ends and different preferences for the means to achieve those ends. Poorly instituted policies, costly mechanisms for monitoring and enforcement, or a sense of illegitimacy and injustice may lead citizens to look for ways to skirt a policy. International-level “solutions” carried out by national governments may seem like the correct scale of governance to address climate change. However, centralizing policies at the largest scale possible increases monitoring and enforcement costs and reduces perceptions of legitimacy and justice, thus undermining the success of collective action [2] p. 105.

Elinor Ostrom's oeuvre of empirical research leads to a relatively simple conclusion: scholars, policymakers, and activists need to challenge their assumption that a single governmental unit is necessary to “solve global collective action problems”; instead, they should recognize “the important role of smaller-scale effects” [2] p. 121. Groups or individuals who push for a single governmental unit need to accept the inevitability that a single-unit approach internationally is not feasible, and would likely be counterproductive at the national or subnational levels. Smaller scales of decision making that overlap one another have more opportunities to overcome the knowledge problems and incentive problems that plague large-scale collective action. For example, competitive markets, as a polycentric system, could produce a technology breakthrough, such as a cost-effective,

zero-carbon energy source. The voluntary adoption of such a technology in the market might have a greater impact in reducing greenhouse gas emissions than the policies of many formal governments. Thus, the meta-polycentric governance structure is important because the small- to medium-sized actions of market firms, civil society organizations, and many levels of government are likely to lead to socially desirable outcomes. In other words, the necessary *governance* to solve a collective action problem may come from other sources than just *government*.

The challenges associated with climate change are perhaps the most complex and variable collective action problems that humanity has ever faced. As such, the governance systems that are needed to address these complex and variable problems must align incentives and promote access to various forms of knowledge. Ostrom articulated this thought clearly:

“The advantage of a polycentric approach is that it encourages experimental efforts at multiple levels, as well as the development of methods for assessing the benefits and costs of particular strategies adopted in one type of ecosystem and comparing these with results obtained in other ecosystems. A strong commitment to finding ways of reducing individual emissions is an important element for coping with climate change. Building such a commitment, and the trust that others are also taking responsibility, can be more effectively undertaken in small- to medium-scale governance units that are linked through information networks and monitoring at all levels.” [2] p. 124.

In another paper, Elinor Ostrom argues that societies face many challenges when designing and implementing institutional rules to help mitigate and adapt to climate change [7]. Ostrom highlights five points to consider. First, scholars, policymakers, and activists must recognize that the causes of climate change are complex. Second, there are epistemic limitations that individuals face because of the complex and dynamic nature of the world. Thus, individuals or small groups of individuals, no matter how well educated, face a challenge in acquiring the relevant knowledge concerning the causes and effects of climate change or any proposed attempt to solve it. Third, public choice concerns arise when making public policies, especially when policymakers are able to engage in opportunistic behavior. These behaviors may have the superficial appearance of reducing emissions, but they may actually exacerbate emissions or impose other relatively high social costs. Fourth, policymakers should allocate sufficient funding so that there can be a variety of policy experimentation. In particular, enough funding should be allocated so that policymakers can monitor and evaluate the costs and benefits of each policy experiment. Without this monitoring and evaluation, there are fewer opportunities to engage in mutual learning. Fifth, policymakers at any scale should be prepared for and expect failures. Trial and error is a major part of experimentation and mutual learning, so the mental models of policymakers should emphasize the failure aspect [7] p. 365.

Building on Ostrom’s arguments, several other scholars have written on a polycentric approach to climate change, and we highlight several important contributions here. Dorsh and Flachsland argue that a polycentric approach has several benefits [43]. First, polycentricity allows people to tailor institutions to site-specific conditions, which allows decision makers to consider a wide array of preferences, competencies, and interactions that individual actors have. Second, polycentricity facilitates experimentation and learning, which in turn leads to robust, innovative, and adaptive institutional arrangements. These processes produce new knowledge and norms that lead to more effective rules, monitoring, and enforcement. Third, a polycentric approach allows people to self-organize to create rules and mechanisms that overcome cooperation dilemmas. It is through the self-organization process that communities can build necessary trust. People have a stronger incentive to cooperate when they trust others and feel that they have participated in the decision-making process.

Cole also builds on Ostrom’s research and emphasizes two principal advantages of a polycentric approach to climate change [3,4]. First, polycentric approaches allow for a

larger number of opportunities for experimentation and learning, which allows policies to improve over time. Second, polycentric approaches foster an environment for communication and interaction, which can take many forms, including formal, informal, bilateral, and multilateral. Communication and interaction among various parties, especially those that disagree, gives them opportunities to build the mutual trust necessary for social cooperation. Global or international policies cannot succeed unless they are undergirded by lower levels of support. Global policies require a wide range of national and sub-national legislation, as well as monitoring and enforcement activities, to give rise to the outcomes desired at the global level. Nongovernmental groups at the local level are likely to be important for fostering an environment of effective and legitimate monitoring and enforcement. Thus, any effective global governance institution must necessarily be polycentric in nature, whether they are related to climate change or not.

In summary, Ostrom and scholars who work in the Ostromian tradition have discussed many of the benefits of a polycentric approach to climate change. However, the benefits have not yet been systematically synthesized to provide an overarching view of a polycentric approach. In the Section 3, we identify and describe six key advantages of polycentric systems, which permit individuals and groups to overcome collective action problems.

3. Six Advantages of Polycentric Systems

3.1. *Competition among Decision Makers*

Competition is one of the most important characteristics of polycentric systems because it can incentivize decision makers to make more socially productive choices than they would have without competitors. For example, competitive markets are polycentric systems that are often characterized by a high degree of competition. Entrepreneurs are alert to and exploit opportunities for profit. Profit signals to entrepreneurs that they are fulfilling consumers' demands, and losses signal that entrepreneurs should direct their time, money, and attention to more highly valued uses elsewhere. In this market process, profits are competed away as entrepreneurs innovate and find ways to provide goods and services at higher qualities and lower prices, holding everything else constant. By contrast, monopolies, as monocentric systems, have much weaker incentives to provide consumers with new innovations or goods of higher quality and with lower prices. The rivalrous nature of the market process induces producers to cater to consumers demands. In other words, competition within polycentric markets channels self-interest into innovative and socially productive forms [44–47].

Civil society groups, in the form of associations, organizations, and clubs, also engage in competition, which provides incentives for them to provide socially productive services or to solve social dilemmas. Civil society groups compete among themselves to entice new adherents, which disciplines the way in which these groups shape their missions, make their rules, and monitor and enforce their bylaws. Unlike markets, which compete on the margins of profit and loss, civil society groups compete on more indirect margins, such as direct benefits and dues from members. If an association fails to fulfill its function, members may defect to another association that they value more. Without the competitive pressure of other groups, any particular group has a weaker incentive to be responsive to its members or effectively fulfill its purpose.

In the literature of polycentricity, perhaps the most discussed instantiation of polycentric systems is in government. Charles M. Tiebout [48] first outlined the concept of interjurisdictional competition between government entities, which has been refined into more modern models of "voting with your feet." When different jurisdictions can create different policies and tax rates, citizens can choose to move among jurisdictions to the one that most closely aligns with their preferences. Some citizens prefer lower taxes and fewer government-provided services, while other citizens prefer higher taxes and more services. Some citizens may want stricter environmental protections and prohibitions on greenhouse gas emissions, while others want laxer protections. Assuming people and

goods are relatively free to move, policymakers in each jurisdiction have an incentive to create policies that entice people and investments to flow in. As such, policymakers have an incentive to respond to constituents' desires or to create policies that will persuade people in other jurisdictions to become constituents. Interjurisdictional competition also provides incentives for policymakers to cater to a wide variety of preferences and to produce better policies at lower costs [27,30].

Public choice concerns are omnipresent in the policymaking process. Since all people are rationally self-interested, including government officials, there are opportunities to use the coercive power of the state to expropriate wealth and redistribute it. In many cases, expropriation and redistribution are socially unproductive, and on a normative level, they are often unjust [49–51]. Interjurisdictional competition is one mechanism among many that can be used to constrain the behavior of policymakers, because if their policies are socially harmful, taxpayers are more likely to flee to other jurisdictions that have better policies. In other words, competition forces policymakers who engage in socially unproductive, opportunistic behavior or tyrannical policies to bear at least some of the costs of their decisions. Of course, interjurisdictional competition is not a panacea because it is costly for many people to vote with their feet. However, a situation with some degree of interjurisdictional competition is more responsive to constituents' desires when compared to a situation with no competition at all.

3.2. Cooperation among Decision Makers

Although competition is important, a polycentric system also facilitates cooperation between various entities, and the cooperation provides opportunities for synergy. Many collective action problems exist simultaneously in every complex society, and the cooperative nature of polycentric systems allows many decision-making centers to work together to solve these many problems at once. These collective action problems come in a wide variety of scales and scopes, and they change dynamically at different rates. Coping with these everchanging collective action problems is a Herculean task. Any single unit of a public administration or civil society group is not well suited to deal with such complexity and dynamism. However, polycentric arrangements allow various decision-making centers to band together when necessary to meet these challenges [52]. Thus, smaller, lower-level entities can come together to create a solution that matches the size of a social problem at a given point in time.

In polycentric systems, smaller-scale decision-making centers can organize on “a quasi-ad-hoc basis to address some larger-scale problems but not others. Different larger-scale problems are addressed by different configurations of smaller-scale units” [36] p. 162. In other words, Vincent Ostrom, Tiebout, and Warren [27] p. 836 argue: “The statement that government is ‘too large (or too small) to deal with a problem’ often overlooks the possibility that the scale of the public and the political community need not coincide with that of the formal boundaries of a public organization.” Monocentric approaches to complex social problems are usually slow to respond to dynamic situations and do not have the on-the-ground knowledge needed to address that complexity. Responsive, adaptable, and flexible systems require a polycentric approach that allows many different centers of power to organize together as necessary [36] p. 163. As Martin [25] pp. 131–132 argues: “Positive and negative externalities come in different sizes. Public service production involves many different tasks with different economies of scale. And environmental factors vary tremendously across different contexts. Governance problems differ in scale, nature, and scope, so jurisdiction should exhibit parallel diversity and complexity to effectively grapple with them.”

In formal government, smaller-scale administrative units, such as states, counties, or cities, can choose to come together, when necessary, to make policies that apply to them all [30] pp. 284–305. For example, the federal government might be too large to address a particular issue but a single state government may be too small. One of the most common forms of this in the United States and Canada is interstate/interprovincial compacts,

in which the federal government is not officially involved. In terms of climate change, the U.S. and Canada have three separate regional agreements to limit the emissions of greenhouse gases, namely the Midwestern Greenhouse Gas Reduction Accord, the Western Climate Initiative, and the Regional Greenhouse Gas Initiative (which includes most states in the Northeast and Mid-Atlantic).

In addition to formal government entities, market firms and civil society associations cooperate on many margins, which allows them to provide goods and services in higher quality and lower cost ways. Cooperation in the market often comes in the form of mutually advantageous contractual arrangements. In civil society, associations, organizations, and clubs cooperate among themselves to accomplish their aims, such as various church groups cooperating to provide aid after a natural disaster.

At the meta-scale of polycentric governance, government, markets, and civil society also cooperate with one another to overcome social dilemmas by collaborating on the creation of rules and mechanisms of monitoring and enforcement. One of the most common forms of this meta-polycentric governance is public–private partnerships (PPPs). PPPs can take many forms and serve many social functions, such as community policing, species conservation, and public health, among others. The degree of a PPP’s success is determined by the institutional arrangements among the various entities. In some cases, a PPP between a government and a firm may be socially wasteful if the arrangement turns into a rent-seeking opportunity for the firm or a rent-extracting opportunity for the policymaker [53–55].

3.3. *Perceptions of Legitimacy That Lead to Coproduction*

For social rules and the associated mechanisms of monitoring and enforcement to achieve their intended ends, the people who are governed by those rules must see them as legitimate and just. In other words, the people being governed must “buy in” to a governance system, otherwise they will ignore or evade the mechanisms of monitoring and enforcement. One way to increase the chances that individuals buy into a governance system and see it as legitimate is to be directly involved in the decision-making process or to have local representatives be involved in the process. Far-removed policymakers who are perceived to be imposing their “outside” preferences on a community are likely to be seen as an illegitimate source of governance [30] pp. 381–391, [56] pp. 111–112.

Part of the issue with buy-in and legitimacy is the fact that any society, especially a global society, has vast heterogeneity in terms of beliefs and values. Polycentricity provides a solution to the problems that arise from such heterogeneity. When individuals perceive that governance institutions conform to their beliefs and values, they are more inclined to uphold those institutions. In many cases, polycentricity does more than just provide a solution; it can actually transform heterogeneity into an asset because different views lead to different approaches, thus leading to more opportunities for experimentation and learning (discussed further in the Section 3.4). Heterogeneity is not inherently a component of successfully overcoming social dilemmas, however. In many cases, heterogeneity harms social cohesion because differences in beliefs and values cause cleavages. Under the right meta-institutional structures, heterogeneity also spurs progress and resilience. Thus, the institutional arrangements that govern a society will shape whether heterogeneity is a blessing or a curse [36] p. 124.

When there are no simple, clear, or indisputable answers to social questions, the answers to such questions will often need to vary. Many of the most difficult social problems have a subjective element to them, such as defining negative externalities and “assigning blame” to them. Additionally, defining a community is often hard, and when it comes to public policies, many people disagree who counts as “the public.” Implementing one answer or solution from the top down may be unjust or tyrannical. Polycentric arrangements provide a multitude of potential answers to these difficult social questions that involve many tradeoffs. Thus, polycentric structures have the advantage of preserving a shared community of understanding at higher levels while also facilitating the ability of decision

makers to cater to a variety of values and beliefs at lower levels, ultimately allowing people to make rules that they view as legitimate [36] pp. 127–128, [56].

Related to the concepts of buy-in, trust, and legitimacy is coproduction, which occurs when a consumer is an essential part of the production process. For example, education is a coproduction process because students, as consumers, must actively engage with teachers, as producers, for true education to occur. Students cannot sit idly by and expect an education; they must coproduce the education with the teacher. This implies that the interests of both parties are considered in shaping the policy or service. Self-governing systems also require coproduction to function well. Citizens of polities and members of civic groups must be coproducers of the rules that govern themselves for the rules to fulfill their intended purpose [57]. The coproduction of governance systems can be difficult and costly, and instead of engaging in the coproduction process, individuals can simply “vote with their feet” to jurisdictions or groups that better fit their preferences. However, since there are non-trivial costs associated with exiting and moving, the coproduction of governance systems becomes both a complement to and a substitute for voting with one’s feet [36] pp. 128–129.

When individuals participate in the coproduction of rules in a polycentric system, they are more likely to see those rules as binding and legitimate, which helps overcome problems of monitoring and enforcement [36] pp. 128–129. In general, for rules to accomplish their intended purposes, people must obey the rule or endure a penalty, meaning that monitors are needed to ascertain when rules are not followed, and enforcers are needed to make sure that penalties are imposed. Without viable monitoring and enforcement, rules may become useless. We acknowledge that sometimes rules are self-enforcing because individuals share the value or preference being sought. In an environmental context, individuals can and do go beyond the “enforced” law to protect the environment. However, many governance systems are less self-enforcing, which leads to the question: Who monitors the monitors? Through coproduction, polities and communities become internally self-policing because members are monitoring other members [36] p. 143. In addition to just monitoring, coproduction can also include the voluntary actions of individuals that contribute to a collective goal. These goals may involve policies or mandates, but individuals often act voluntarily as they gain knowledge of particular issues or their attitudes change. In sum, workable systems of rules require a polycentric approach that involves the legitimacy and coproduction of rules and mechanisms of monitoring, enforcement, and voluntary action.

3.4. Experimentation and Mutual Learning

Polycentric systems foster an environment of experimentation and mutual learning because the multiple spheres of decision making can try different approaches to solve social problems. Most social dilemmas are complex, meaning that decision makers suffer from severe epistemic limitations. Centralized decision makers do not have access to the local, dispersed, tacit, and inarticulate knowledge that is necessary to overcome complex social dilemmas [58–61].

A realistic view of the world acknowledges that decision makers are fallible. For institutions to work well, they should have the means of discovering and correcting errors. In other words, one of the main functions of institutions is to facilitate social learning. Some institutional arrangements are better suited to facilitate rapid learning in the face of complex and dynamic social problems, while others are slower [36] p. 115. As Martin [25] p. 131 argues, “[P]olycentric systems offer citizens more opportunities to correct governance errors. Errors are inevitable, but institutions are not all equal in their ability to correct them. [. . .] Distributed authority makes it more likely that errors will be detected, because different jurisdictions can adopt different practices. It also creates more avenues by which individuals and groups can seek to implement change.”

Polycentric institutional arrangements can serve as a “laboratory” in which individuals at lower levels can use their local, dispersed, tacit, and inarticulate knowledge to devise solutions to social problems. A pure monocentric system, by contrast, can only

try one policy at a time, slowing experimentation and learning. The existence of multiple decision-making centers implies that there is a larger potential for entrepreneurship to take place. Monocentric systems have few opportunities for creativity, innovation, and entrepreneurship because decisions can only be made by individuals at the highest level. However, polycentric systems allow for many instantiations of creativity, innovation, and entrepreneurship at different levels and locations [62] pp. 116–118.

Within the formal government, overlapping and nested arenas of policymaking allow officials to experiment simultaneously with different approaches. Policymakers in other places or at other levels can observe and learn from those experiences. Then, they are able to tailor any lessons learned to fit their local circumstances. Markets and civil society also engage in experimentation and mutual learning. Firms in a market can observe their competitors and discover new innovations based on the successes and failures that they see. In civil society, associations can experiment with their own approaches and learn from the successes and failures that they see in other associations.

3.5. Institutional Resilience and Robustness

Polycentric systems are more institutionally resilient and robust than centralized systems. Resilience refers to the capacity to adapt to and recover from difficulties quickly, and robustness refers to the ability to withstand adverse conditions. In other words, institutions are robust if they are well prepared to cope with stress, and they are resilient if they can bounce back quickly after they have endured stress. The two concepts are often interrelated but distinct.

When decision-making power is dispersed, institutions become more resilient and robust for at least two reasons. First, any institutional failure affects only a part of the system, not the entire thing. Any failure in a purely monocentric system will be inherently systemwide [30] p. 293. Since there is an element of decentralization in a polycentric system, decision makers at lower levels often have better knowledge and incentives to discover a problem before it grows too large. Other decision-making centers can step in and provide solutions if a failure happens elsewhere in the system. Second, since polycentric systems have multiple margins of contestation, they have a built-in system of checks and balances, as well as backstops. Centralized power often provides an environment that is conducive to the abuse of power, but polycentric systems work in a Madisonian way, allowing one center of power to push back against others [56] pp. 9–12.

Although many monocentric systems can be robust, they are often not especially resilient or adaptable. The benefit of polycentric systems is that they can be both robust and resilient simultaneously, and resilience is perhaps the more important feature because of the dynamic and unpredictable nature of the world. Monocentric systems that have been designed to be robust against past shocks become vulnerable to new, unforeseen problems. Thus, many monocentric systems can be robust but fragile because they are designed to cope with known problems, not unknown ones [62] pp. 105–107.

When we introduce human foibles into the struggles of coping with complex and dynamic situations, outcomes can become even worse. For example, regulations create incentives for people to act entrepreneurially, but the forms of that entrepreneurship may be socially harmful. Economist Israel Kirzner [63] called this “superfluous discovery”, in which people discover ways to get around regulations in socially unproductive ways. Thus, even seemingly robust institutions can be undermined when checks, balances, and backstops do not exist to constrain opportunistic and socially harmful behavior [62] p. 107. Like Kirzner, Elinor Ostrom [64] p. 255 articulated this fact: “As soon as one design has proved itself in one environment, innovations in strategies adopted by participants or changes in the environment in which a humanly designed system is in operation will produce unexpected results.”

Resilient institutions that are able to cope with complex, dynamic situations will have a relatively high degree of redundancy in a variety of ways and at a variety of scales. One-size-fits-all solutions are less equipped to cope with uncertainty and risk because

of the lack of checks, balances, and backstops. Elinor Ostrom argued that a polycentric arrangement is more resilient because, first, “information about what has worked well in one setting can be transmitted to others who may try it out in their settings”, and second, “when small systems fail, there are larger systems to call upon—and vice versa” [64] p. 283. Thus, the separation of decision-making power in a polycentric system implies that there will be many failures in the system, but those smaller failures become valuable learning opportunities, not systemwide catastrophes. Polycentric arrangements “drastically reduce the probability of immense failures for an entire region” [64] p. 284. In other words, Elinor Ostrom [28] p. 8 explained why polycentric systems are more resilient and adaptable than monocentric ones:

“Reliance on any single set of decision rules exposes all to the risk of total institutional failure. In an imperfect world where institutions are filled with weaknesses, redundancy in organizational arrangements may prevent the failure of any one set of decision rules from seriously handicapping us, as citizens, in accomplishing some of our goals. Multiplicity of arrangements also enables us to test the relative performance of different types of institutional practices and thus evolve new solutions to different kinds of problems.”

Additionally, polycentric systems are more resilient because they generally have lower information costs and more opportunities for experimentation and learning than monocentric systems. When unexpected problems arise, polycentric systems can try more approaches at once, speeding up the process of learning, and thus speeding up the process of recovery. Decision makers in monocentric systems face relatively high costs of changing course if they make an error. However, the relatively larger number of decision makers in polycentric systems means that one center can decide unilaterally to change course, thus mitigating the chance of systemwide failure [62] p. 118.

3.6. Emergent Outcomes

Polycentric systems facilitate emergent outcomes that are socially desirable but not centrally planned. In other words, many smaller-scale actions can aggregate into large-scale outcomes, which are the outcomes that central planners want but did not actually plan. A global-level consensus is not necessary to solve global problems. When civil society, markets, and lower levels of government engage in competition, cooperation, and contestation, the desired outcome can, and often does, emerge from those various interactions [30] pp. 299–300, 321–326.

The emergent properties of polycentric orders are similar to the emergent properties of the market process. The work of F. A. Hayek on spontaneous order influenced the Ostroms’ thought on polycentricity. Hayek argued that centralized economic planning is unattainable because the planners do not have the required knowledge necessary to coordinate an economy [58–60,65]. Even though markets do not have planners at the highest level, goods and services tend to flow to the people who demand them. This is reminiscent of the “invisible hand” that Adam Smith and other economists have described [66].

Since polycentric systems are complex, adaptive orders, they can address social problems without a rigid, hierarchical system of public administration. The processes of competition, coordination, and contestation within polycentric systems, as well as the diversity of beliefs and preferences within each node, implies that the outcomes from polycentric systems are not purely deliberate. The complex, adaptive nature of polycentric systems necessarily means that each decision-making center in the system will be constantly reacting to changing conditions and mutually adjusting to one another. In other words, polycentric systems are characterized by constant flux. The processes of competition, cooperation, and contestation among various decision-making centers allow workable solutions to emerge, while less workable solutions tend to be eliminated over time [62] pp. 64–66, [67].

The emergent features of a polycentric system may be more or less desirable, depending on an individual’s particular normative views. However, if many people find the outcomes of a polycentric system to be undesirable, the most workable solution is not to

centralize decision-making power. The emergent properties of polycentric systems can be changed by changing the constitutional rules of the system. When meta rules are changed, decision-making processes and incentive structures will also change, leading to a different set of emergent outcomes [62] pp. 64–66, [67].

4. A Polycentric Approach to Climate Change

4.1. *The Nested and Complex Nature of Climate Change*

Human-caused climate change affects both social and environmental systems, creating multiple simultaneous collective-action problems that are complex, dynamic, and nested within one another. As the IPCC [1] p. 9 has indicated, climate change has brought and will continue to bring “[w]idespread, pervasive impacts to ecosystems, people, settlements, and infrastructure” that result from “observed increases in the frequency and intensity of climate and weather extremes, including hot extremes on land and in the ocean, heavy precipitation events, drought and fire weather.” There is a high likelihood that climate change will continue to exacerbate heat-related human mortality, warm-water coral bleaching, drought-related tree mortality, sea level rise, ocean acidification, species extinction, glacial retreat, permafrost thaw, food insecurity, water insecurity, food- and water-borne disease, and crop damage, among many other problems [1,68].

Governing the processes of mitigation and adaptation to climate change requires a governance structure that can respond to such complexity and dynamism at many scales and scopes, as well as the vast array of preferences and beliefs that a global population holds. Additionally, the complex and dynamic nature of climate change brings about both risk and uncertainty for decision makers. A polycentric approach allows societies to adapt to complexity, dynamism, risk, and uncertainty through the processes of competition, coordination, and contestation.

A polycentric approach to policymaking contrasts with a “monocentric” approach, which is centralized and top-down. In a more monocentric approach to public policymaking, the highest levels of politicians or technocrats choose what they perceive to be the best course of action and use the coercive power of the state to implement their policies. All formal policymaking will involve the coercive power of the state to some degree, even in polycentric governance systems. However, more polycentric governance systems will constrain formal power and facilitate voluntary agreements within markets and civil society. Government systems that verge on a monocentric arrangement are likely to devolve into authoritarianism and tyranny due to a lack of checks and balances on formal power. However, even under authoritarian governments, the governance structure of a society will likely be somewhat polycentric because black markets and underground civic groups provide ways for people to engage in collective action, as was seen in the Soviet Union [69]. In the context of the United States, a monocentric policymaking approach is often associated with reliance on actions by the federal government only. As we discussed in Section 2, pure monocentric systems are rare because decision-making power is not easily centralized. Therefore, critiquing monocentrism for its faults may not be especially productive because it is not applicable to the real world. The important aspects to focus on are the *degree* to which decision making is polycentric and the *institutional arrangements* in which those polycentric decisions are made. In other words, the problem becomes one of comparing different arrangements for polycentrism. A highly centralized system may fail to achieve its intended results, but a highly decentralized system may also fail. Polycentric systems achieve their desired results when the institutional arrangements set up socially productive incentives and promote the discovery and dissemination of relevant knowledge.

It is not immediately clear what the best policies or approaches are for dealing with the complexity, dynamism, and uncertainty associated with climate change, which suggests a polycentric approach. Since the scale and scope of such problems are unprecedented, decision makers face a significant knowledge problem. They do not know exactly which approaches are best, and they do not know the full extent of the tradeoffs or unintended consequences that their actions will have. Decentralization along many margins, while still

incorporating checks, balances, and backstops through the polycentric order, allows decision makers to discover, exploit, and mutually learn many forms of knowledge, especially those forms that are dispersed, tacit, and inarticulable.

Additionally, perceptions of legitimacy and coproduction are necessary in coping with climate change because individuals in many places and at various levels need to be engaged in the processes of rulemaking, monitoring, and enforcement. Without coproduction, governance systems for climate change are unlikely to succeed because of the ubiquity of greenhouse gas emissions and the interconnectedness of global supply chains. Individuals, families, businesses, communities, organizations, and polities of all sizes must change their behavior if greenhouse gases are to be reduced. Thus, the rules that govern how individuals and groups should change behavior must be seen as legitimate so that they contribute to the coproduction of the public good they are trying to achieve. Legitimacy, social trust, and coproduction align the incentives of individuals to modify their behavior toward the social benefit. Thus, in the face of the dire collective action problem of climate change, polycentric systems facilitate access to the best knowledge and incentives, as well as achieving buy-in from the people who are to be governed.

The existence of many decision-making centers necessarily means that certain responses will fail. Localized failures are a necessary, and often painful, process of experimentation and learning in order to cope with complex, dynamic social dilemmas. In some areas, the costs of rule enforcement are too high. For example, during COVID-19, lockdown policies in less developed countries sometimes had unintended consequences that exacerbated deforestation and environmental destruction because ordinary citizens were trying to survive the economic losses. However, at least in terms of emissions, lockdowns in many rich countries led to reductions due to less driving, etc. While lockdowns in richer countries did not have the same environmental unintended consequences as in poorer countries, rich countries experienced other unintended consequences involving huge economic and societal impacts. Recognizing differences in both preference and capacity relative to other desired goals, such as feeding one's family, is one of the key benefits to polycentricity and self-governance. One-size-fits-all rules that are too restrictive may push individuals into illegal, but morally defensible, actions with even worse effects. A polycentric approach would allow for accommodations and cross-distributional support, thus avoiding the harms introduced by a rigid, top-down, bureaucratic approach. In short, the combination of localized failures and successes is easier to cope with than a system-wide, monocentric failure.

Even though polycentricity is more than just simple decentralization, much of the current literature is often framed in a way that implies the purpose of local action is to obtain buy-in to national and international policy [70]. Instead, we echo Elinor Ostrom's argument that local action in lower levels of government, markets, and civil society may generate the desired outcomes that high-level officials want, even if the high-level officials did not design the policies or approaches. Additionally, the concept of coproduction at the individual level is important because as individuals strive to solve social problems—they come up with innovative, context-based solutions that may not have been discovered by more centralized approaches. Thus, polycentric governance systems are beneficial precisely because they allow the authority to act and create solutions at many nodes. As Andersson and E. Ostrom [52] p. 71 have argued, local institutions are certainly important, but "institutional arrangements operating at other governance scales—such as national government agencies, international organizations, NGOs at multiple scales, and private associations—also often have critical roles to play" in governance regimes.

When zooming out to the global scale, several questions arise regarding polycentric governance and climate change, such as how and why has polycentric governance differed across space and time? At a national level, in most well-functioning democracies (and, to a large extent, for the EU), polycentrism in climate change has existed for some time. Many other countries and international entities, such as the United Nations Framework Convention on Climate Change (UNFCCC) have acknowledged the importance of decentralization

in climate change governance. In fact, the UNFCCC has shifted its stance in recent years from the Kyoto Protocol of 1997 to the Paris Agreement of 2016 (also known as the Paris Accords or the Paris Climate Accords). Both the Kyoto Protocol and the Paris Agreement were similar in that the signatory countries committed to implement certain emissions-reduction targets. However, some of the most significant differences between the Kyoto Protocol and the Paris Agreement was how the targets were made and which countries were included. Under the Kyoto Protocol, only developed countries were obligated to meet specific targets and timetables for greenhouse gas emissions. China was not considered a developed country at the time, and the United States chose not to participate in the Kyoto Protocol, thus leaving out the two largest emitters of greenhouse gases [71]. On the other hand, the Paris Agreement was meant to be more self-enforcing because each country could choose their own pledge. In other words, the Paris Agreement was more polycentric in the sense that it allowed countries to embed their self-chosen climate measures within their domestic economic policies, which would give individuals in each participating country a stronger incentive to comply with the climate pledge [72,73]. However, the self-enforcing nature of the Paris Agreement has not been as strong as many policymakers had expected. Many of the Nationally Determined Contributions have not been fully implemented by some of the world's largest economies, which has left a gap between what countries had committed to and how much actual emissions have decreased [74].

The polycentric nature of human interaction is apparent in every sector—government, markets, and civil society. Increasingly, political entities embrace a more decentralized approach to climate change policies. For example, in recent decades, the European Union has adopted a highly polycentric approach to climate change. As Finck [75] p. 444 observes, “Climate change regulation in the EU constitutes a mosaic, composed of a multitude of policies, formulated at various levels, which interconnect and intertwine. This regime can best be qualified as ‘polycentric’ and ‘porous’ in nature.” Finck argues that many scholars miss the importance of sub-national authorities in the EU because most analysis focuses on the EU government and the governments of the members states. However, when all the policymaking abilities of sub-national authorities in the EU are considered, climate change policy is much more nuanced. Sub-national authorities in the EU both implement the policies of the members states and the EU, but they also create their own policies, standards, and rules for climate change mitigation and adaptation [75].

Polycentricity in markets, defined in part as competition and free trade among many firms and individuals, is correlated with improving environmental conditions past a certain level of development. Relatively free markets are polycentric due to the presence of many competing and cooperating firms that engage in arbitrage and innovation. The Economic Freedom of the World Index, created by the Fraser Institute, helps to capture the degree to which markets are free, and thus, by implication, expressing how polycentric markets are. Between 2000 and 2020, the average economic-freedom rating increased to 6.84 from 6.59. The average score in 2019 was 7.00, but it declined in 2020 to 6.84, due largely to government-imposed restrictions during the COVID-19 pandemic [76]. As economies become more free and more prosperous, the potential for environmental improvements increases [77], such as companies and individuals choosing to invest in a cleaner environment.

In terms of civil society, the United Nations documents many bottom-up approaches for coping with climate change [78]. For example, in several African countries, Community Action Against Plastic Waste is working to build the largest community of climate youth leaders in the world, with an emphasis on reducing plastic waste [79]. The Environmental Justice Foundation works to secure international protection for climate refugees across the globe [80]. In South Korea, Hope To The Future Association seeks to reduce plastic waste through several campaigns led by youth [81]. These few examples are among the hundreds of civil society organizations that are springing up across the globe to address the diversity of complex social dilemmas associated with climate change. Civil society organizations are important because participants use their local and tacit knowledge to help address social problems. Additionally, civil society organizations may often induce coproduction

because local community members may feel more closely connected to the mission of these groups. Sometimes government funds help pay for these civil society organizations, but that does not necessarily undermine the epistemic or coproductive properties of these groups. However, too much dependence on government money may skew the incentives of decision makers in these groups, and they could prioritize rent seeking rather than social governance [82,83].

Of course, the degree of polycentric governance also differs from country to country, due to political, economic, and social factors. There is not one easy explanation as to why certain countries have a more polycentric approach than others, and it is beyond the scope of this paper to discuss those reasons in depth. The United States is one of the most polycentric nations (as discussed in the Section 4.2) due to a history of a federalist government, robust markets, and a thriving civil society [42,56,84]. Similarly, the EU, as discussed above, is polycentric on many margins, including its policies and approaches to climate change [75,85]. Other countries, such as China, have taken a much more top-down approach. Especially in terms of climate policy, modern China's centralized approach has had some successes, but many of its policies fail to achieve the stated goals [86–88].

One significant question that remains is: "What have been the consequences of using a polycentric approach?" It is difficult to measure success directly because of the complex, overlapping nature of decision making. Since social outcomes emerge from the complex interaction of many nodes, it is difficult, and potentially impossible, to pinpoint one decision and say that it is the "source" of a result. Since 2000, more than 20 countries, including France, Germany, the Netherlands, the United Kingdom, and the United States, have reduced their annual greenhouse gas emissions while also allowing their economies to grow [89]. These countries are also some of the most polycentric, with many spheres of political decision making, competitive markets, and robust civil societies.

4.2. Polycentric Approach for Coping with Climate Change in the United States

Within its meta-polycentric arrangement, the United States has steadily reduced total emissions and per capita emissions over the past few decades. In 2000, the CO₂ emissions per capita in the US were 20.5 metric tons. By 2019, the CO₂ emissions per capita were reduced to 14.7 metric tons (for data on per capita CO₂ emissions in the US by year: <https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?locations=US> accessed on 15 December 2022). In 2000, the US emitted nearly 5.8 million kilotons of carbon, but by 2019, total emissions had been reduced to roughly 4.8 million kilotons (for data on total CO₂ emissions in the US by year: <https://data.worldbank.org/indicator/EN.ATM.CO2E.KT?end=2019&locations=US&start=1990&view=chart> accessed on 15 December 2022).

The decline in US emissions is the result of several factors, which are directly related to the US's meta-polycentric governance structure. While we cannot outline all the reasons here, we want to highlight a few important ones.

First, natural gas prices declined relative to coal prices due to the fracking revolution. Since natural gas burns "cleaner" per unit of energy than coal, replacing an equivalent amount of coal with natural gas reduces overall carbon emissions and other pollution [90]. The technological advances that led to the fracking revolution and the outcompeting of coal by natural gas are a result of the polycentric nature of markets. The interfirm competition and cooperation that are inherent to liberal markets lead to the "creative destruction" that is necessary for such social progress [91] pp. 81–86.

Second, there were policies with other objectives, such as stricter energy efficiency standards and local air quality standards, which cut greenhouse gas emissions as a co-benefit. Across the country, state and local governments enacted variety of policies to improve energy efficiency, thus indirectly reducing carbon emissions [92].

Third, several state and interstate policies reduced emissions before the Paris Agreement was passed. For example, California's AB32 program was enacted several years before the Paris Agreement and helped to drive down the most populous state's greenhouse gas emissions. The California program recently expanded to include collaboration with Quebec,

and now constitutes one of the largest cap-and-trade programs in the world and the only one managed by sub-national governments in different countries [93,94]. In addition, the Regional Greenhouse Gas Initiative was established several years before the Paris Agreement among states in New England and the Mid-Atlantic regions to limit power-plant greenhouse gas emissions [95]. These examples suggest that even when national emissions mitigation policies are limited, states, multi-state regions, and localities crafted mitigation policies of their own.

One of the most illustrative examples of the greater flexibility associated with polycentric governance of climate change during the past two decades has been the US's experience in relation to the Paris Agreement. The Paris Agreement arose from a combination of pressures from governments, businesses, and civil society [96]. The US had formally joined the Paris Agreement in September 2016, but on 1 June 2017, President Donald Trump announced that the US would no longer participate.

The US withdrawal from the Paris Agreement in 2017 had little impact on the emissions trajectory largely because of energy market changes, effects of non-climate policies, and sub-national initiatives that had started before the Paris Agreement was negotiated and continued after the US withdrawal. Between 2015 and 2017, few, if any, significant national policies for reducing emissions were enacted [97–99]. The continuation of other drivers of greenhouse gas reductions illustrates a different element of polycentric resilience—the federal government could not force lower levels of government to suspend their efforts. Despite this abrupt and sudden shift in federal policy, the polycentric governance structure of the US allowed the country to continue to reduce total and per capita emissions even without formal adherence to the Paris Agreement.

During the time that the US was not adhering to the Paris Agreement, the six advantages of polycentric systems were visibly doing the work of reducing emissions. First, the polycentric nature of the federalist system allowed states to both create policies for themselves and cooperate among themselves, which facilitated resilience and robustness in the face of the federal government's drastic policy changes [70,100,101]. States have implemented a wide variety of policies that are currently aiding climate change mitigation, at least to some degree. For example, Colorado invested USD 340+ million in climate and air quality solutions, such as the expansion of electrified transportation. In 2020, California implemented a phase-out of gasoline-powered passenger vehicles by 2035 to reduce the state's demand for fossil fuels, advance its climate goals, and reduce air pollution. Connecticut enacted a law to achieve a zero-carbon electric supply by 2040, designed to fully transition the state's electricity supply away from natural gas and oil. In July 2021, Illinois began its EV Rebate Program, which was intended to reduce emissions from the transportation sector and make EVs more affordable for consumers. In June 2022, Massachusetts released a Clean Energy and Climate Plan for 2025 and 2030 (2025/2030 CECP) to achieve a 33 percent reduction in greenhouse gas emissions by 2025 and a 50 percent reduction by 2030. Massachusetts's plan would also increase net carbon sequestration by 25 percent in 2030 [102].

Additionally, following Trump's announcement of withdrawing from the Paris Agreement, the governors of several states formed the US Climate Alliance. This group's goal is to work toward the objectives of the Paris Agreement at the state level. In total, twenty-four states and two territories eventually joined the US Climate Alliance. Some of the most populous states joined, including California, New York, Pennsylvania, Illinois, Michigan, North Carolina, Minnesota, New Jersey, Massachusetts, Virginia, and Washington (for more information on the US Climate Alliance, visit this website: <http://www.usclimatealliance.org/about-us> accessed on 15 December 2022).

The Mayors National Climate Action Agenda was formed in 2014 at the city level in 435 cities, including New York, Los Angeles, Chicago, Houston, Philadelphia, and Boston, and is "committed to setting greenhouse gas emission reduction targets, developing climate action plans with those targets in mind, initiating a project that complies with the California cap and trade program, and registering that project with the Cli-

mate Action Reserve” (for more information on the Mayors National Climate Action Agenda, visit this website: <https://www.clintonfoundation.org/commitment/clinton-global-initiative/mayors-national-climate-action-agenda/> accessed on 15 December 2022). Later, the goal shifted to “adopt, honor, and uphold the commitments to the goals enshrined in the Paris Agreement” (For the full statement from the Climate Mayors in response to President Trump’s withdrawal from the Paris Climate Agreement, visit this website: <https://medium.com/@ClimateMayors/climate-mayors-commit-to-adopt-honor-and-uphold-paris-climate-agreement-goals-ba566e260097> accessed on 15 December 2022). The Clinton Global Initiative gave the Mayors National Climate Action Agenda one million USD in 2014 as start-up funding, which is another form of polycentric governance, where a civil society group cooperates with various levels of government.

We should note that it is difficult to ascertain the exact magnitude of the reductions that resulted from expanded state and city-level alliances for action on greenhouse gas emissions. However, the cooperation and coordination of state and city leaders made climate governance more robust and resilient than it would have otherwise been. Many state and city leaders were able to continue working towards the same goals as the Paris Agreement, even though the federal government was not officially participating. Thus, if we view the withdrawal from the Paris agreement as a government “failure”, then the dispersion of power throughout the polycentric system contained the effects of that failure. If all climate policy had been centralized into the federal government, the failure would have been systemwide, and less progress would have been made during the years that the US was not participating.

In addition to state and local policies, markets and civil society also served as a check and balance on the federal government’s decisions. In April 2017, the Center for Climate and Energy Solutions, a civil society organization, called on the President to remain in the Paris Agreement. Several of the US’s largest and most influential companies signed the Center for Climate and Energy Solutions’ letter to President Trump, writing, “Climate change presents U.S. companies with both business risks and business opportunities. U.S. business interests are best served by a stable and practical framework facilitating an effective and balanced global response. We believe the Paris Agreement provides such a framework” (to view the letter in full, visit this website: <https://www.c2es.org/wp-content/uploads/2017/04/business-letter-white-house-paris-agreement-final-04-26-2017-1.pdf> accessed on 15 December 2022). The signatories included companies such as Apple, BP, DuPont, Google, Microsoft, Shell, and Walmart. Since business leaders perceived the Paris Agreement as legitimate, they were more inclined to participate in the coproduction of more climate-friendly results. However, companies might have many motives behind these climate-friendly stances. For instance, it may be strategic for companies to make such statements as a form of advertising and virtue signaling, known as “greenwashing” [103–105]. Moreover, these large corporations may perceive such regulation as a competitive advantage over smaller competitors who may be unable to absorb the costs of implementing such policies. By raising costs of entry, they are able to enhance their own market positions while signaling to their customer base [54,55].

On 19 February 2021, the US formally rejoined the Paris Agreement roughly four years after it left. Even without formal participation at the federal level for four years, the competition, cooperation, and contestation of the US’s meta-polycentric governance structure allowed total and per capita emissions to continue their general downward trajectory. Thus, these four years show how desired outcomes can emerge from the combination of actions at lower levels of decision making, without necessarily requiring top-down direction from the federal level.

Many public policies in the US, at the federal, state, and local levels, have focused mainly on mitigation. Formal policies for adaptation have been far less numerous [106]. Regarding the period from 2000 to 2020, evidence seems to suggest that formal policies have made some progress with mitigation but little progress in adaptation, even moving backwards in certain respects [107–109]. Only time will tell how and to what extent

government entities will focus on adaptation policies. However, the meta-polycentric ordering of US society has helped with mitigation in other ways, including through market and civil society mechanisms.

Adaptation, perhaps even more than mitigation, requires multiple centers of decision-making because of uncertainty. Nobody can have perfect foresight to know the particular effects of climate change in a specific place. Allowing lower levels of government, markets, and civil society groups to experiment with different approaches allows for a larger scope of potential innovation, social learning, and deliberation. Thus, such adaptive processes would be especially difficult to create in a centrally planned, top-down fashion because such knowledge cannot be known *ex ante*. Of course, high-level political decision makers can facilitate self-organization, coordination, and collaboration by creating a legal and regulatory environment that is conducive to innovation, social learning, and deliberation [110].

Cooperation among markets, civil society, and government within a polycentric order helps with adaptation to climate change. For example, some nonprofit organizations pay people to change their behavior and adapt to new conditions caused by climate change. In Texas, drought has been a common occurrence in the past few decades. Nonprofit organizations, such as Texas Water Trade, are paying farmers to consume less water or even leave it in the ground. Texas Water Trade's Aquifer Resilience Fund uses USD 1.275 million to finance conservation agreements in the Edwards-Trinity Aquifer. This money largely comes from grants from the Natural Resources Conservation Service, Texas Water Development Board, and National Fish and Wildlife Foundation [111]. Thus, the polycentric, cooperative interactions between markets, nonprofit entities, and government agencies induce people to better adapt to the longer, harsher droughts caused by climate change.

5. Conclusions

Human-caused climate change is undeniably a global concern that affects the natural environment and human societies [1]. Despite the magnitude of the current problems and potential problems in the future, addressing climate change is an especially difficult collective action problem at the largest possible scale. Overcoming such collective action problems is best achieved using a polycentric approach, as Elinor Ostrom and scholars working in her tradition have argued [2–5,7–9,43]. Competition, cooperation, and contestation among various decision-making centers in government, markets, and civil society allow polycentric systems to produce environmental results that are greater than the sum of their parts.

We have described six distinct advantages that polycentric systems have for coping with climate change. First, competitive pressures incentivize decision makers to respond to the desires of constituents/customers/members and limits their ability to abuse their power. Second, complex, dynamic social problems, such as climate change, require many different approaches. Lower-level decision makers can cooperate with each other in many combinations to match the scale and scope of any particular sub-problem of larger, more complex problems. Third, self-governance increases the legitimacy of decisions made and encourages coproduction by the governed. Fourth, when many decision makers try different approaches simultaneously, others can learn from the successes and mistakes they see. Each decision maker can then adjust and adapt their approach to their unique circumstances. Fifth, polycentric systems are more robust and resilient than monocentric systems because they can adapt relatively quickly to unforeseen circumstances and shift to meet new problems. Sixth, polycentric orders are not centrally planned, but through the interactions of lower levels, socially desirable outcomes can spontaneously emerge. These outcomes are often ones that central planners would have chosen if they could have, but the emergent order negates the need for central planners to orchestrate agreement among various parties, create rules, and devise effective means of monitoring and enforcement.

Since coping with climate change, whether through mitigation or adaptation, is a highly complex problem, any collective action solution must embrace such complexity. The causes behind climate change and the potential responses to it are dynamic and occur

over a wide variety of scales and scopes. Additionally, preferences and beliefs differ vastly between individuals and groups. Polycentric governance systems open opportunities for individuals and societies to manage complexity, dynamism, risk, and uncertainty by aligning incentives and facilitating the discovery and communication of knowledge.

The US's experience over the past few decades shows how a meta-polycentric structure can help a society cope with climate change, even when national policy makers do not act. The combination of government policies at various levels and in various locations, combined with the contestation and cooperation provided by market firms and civil society organizations, resulted in reduced total carbon emissions and per capita emissions. In the US's meta-polycentric governance structure, inaction or limited action at the federal government level does not spell disaster for governance overall. Its meta-polycentric system is resilient to such failures. Further research should explore the intricacies of the US's polycentric system and how it helps (and in some cases, hinders) effective actions for the mitigation of climate change.

Despite the benefits of polycentric systems, there are at least three potential criticisms of such an approach to climate change. First, some may argue that polycentric systems may be too slow, since climate change is too big and too pressing a problem to wait for a polycentric approach to work. This argument neglects two important features: mutual learning and institutional resilience. A top-down, one-size-fits-all system may be faster at imposing a policy, but there is no way to know *ex ante* whether that single policy will produce the intended results, what the exact tradeoffs will be, and what unintended consequences will result. If that policy does not achieve its intended result or imposes more social costs than benefits, then the policy will need to be revoked and another will need to replace it. The process of learning will be much slower, since only one policy can be tried at a time, and any failure means systemwide failure, leaving the system less resilient to uncertainty. The complex and dynamic nature of climate change increases the chances that a single policy will fail to reach its objective. As such, many approaches being simultaneously implemented and tested increases the speed at which workable solutions will be discovered, leaving the system more resilient to unforeseen circumstances that might arise.

Second, some may argue that large degrees of decentralization in polycentric systems may lead to a "race to the bottom." Many legal jurisdictions may have a policy culture of not caring about climate change. As such, they may make policies that not only do not help reduce climate change but may even make it worse. Forcing a top-down policy onto places that do not care about climate change may provoke individuals to ignore or actively subvert the rules that they feel are imposed on them. Allowing a diversity of overlapping approaches, even in the same place, can mitigate any attempts to undermine climate change action. For example, even if one state does not pass climate change legislation, both markets and civil society can provide governance that the state government does not. Markets may offer consumers goods and services that are produced with fewer emissions. Associations, clubs, and nonprofits might raise money to incentivize people to change their behavior, such as making buildings more energy efficient or production processes less carbon intensive. The checks and balances of a meta-polycentric system with government, civil society, and markets make it difficult to have a race to the bottom along many margins.

Third, some scholars in the literature have argued that one well-established "weakness" of the international level of climate-related policymaking is that it is not monocentric. Climate change policy is already and unavoidably polycentric, since the world is made up of sovereign nation-states. There is not a single global decision maker, and there never can be. We argue that global solutions are more likely to emerge with an expanded polycentric approach that includes a much larger scope than just national-level governments. From the bottom-up, the meta-polycentric structure of governments, markets, and civil society organizations creates more opportunities for experimentation, learning, resilience, and trust-building [6].

This research has two main implications. The first implication is one of pragmatism. For scholars, policymakers, and citizens who care about addressing climate change in a realistic and timely manner, a polycentric approach will likely be the most viable path moving forward. An international consensus, or even broad consensus within large countries, is unlikely in the near future. Therefore, the complex interactions among various levels of government, firms in the market, and non-governmental organizations is the most pragmatic way to move forward with mitigation and adaptation strategies related to climate change.

Related to pragmatism, the time involved in achieving global policies means that such market or social innovations may be delayed by the political difficulty of passing global policies. By contrast, more independent polycentric actors in markets, civil society, or local governments can move quickly to take advantage of such developments. This results in change even as the official international policies slowly advance. Of course, this slow pace may also move in the exact opposite direction if the international or national rules and regulations limit what localities and businesses can do. Such regulations could change the incentives to reduce innovation by opening opportunities for rent seeking and regulatory capture by large companies.

The second implication is related to the normative considerations of a polycentric approach. People who care about liberal, democratic self-governance should prefer polycentricity because top-down, centralized approaches often lead to illiberal and undemocratic outcomes. Additionally, people who care about the abuse of state power should appreciate polycentric systems because of the presence of many checks, balances, and backstops. Vincent and Elinor Ostrom's work divided governance systems into two broad categories: governing *over* others and governing *with* others. The essence of democracy is to co-govern *with* other citizens, and this relationship of co-governing requires citizens to see each other as moral equals under a general sense of tolerance. Through polycentric systems, people can discover ways to govern themselves democratically, whether that governance comes in formal government or civil society. Monocentric systems, however, inherently require a select few to govern *over* others, which minimizes the ability of people to choose their own governing institutions. People who value the classical liberal positions of individual liberty, constrained government, and the rule of law should favor a polycentric approach to addressing climate change.

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