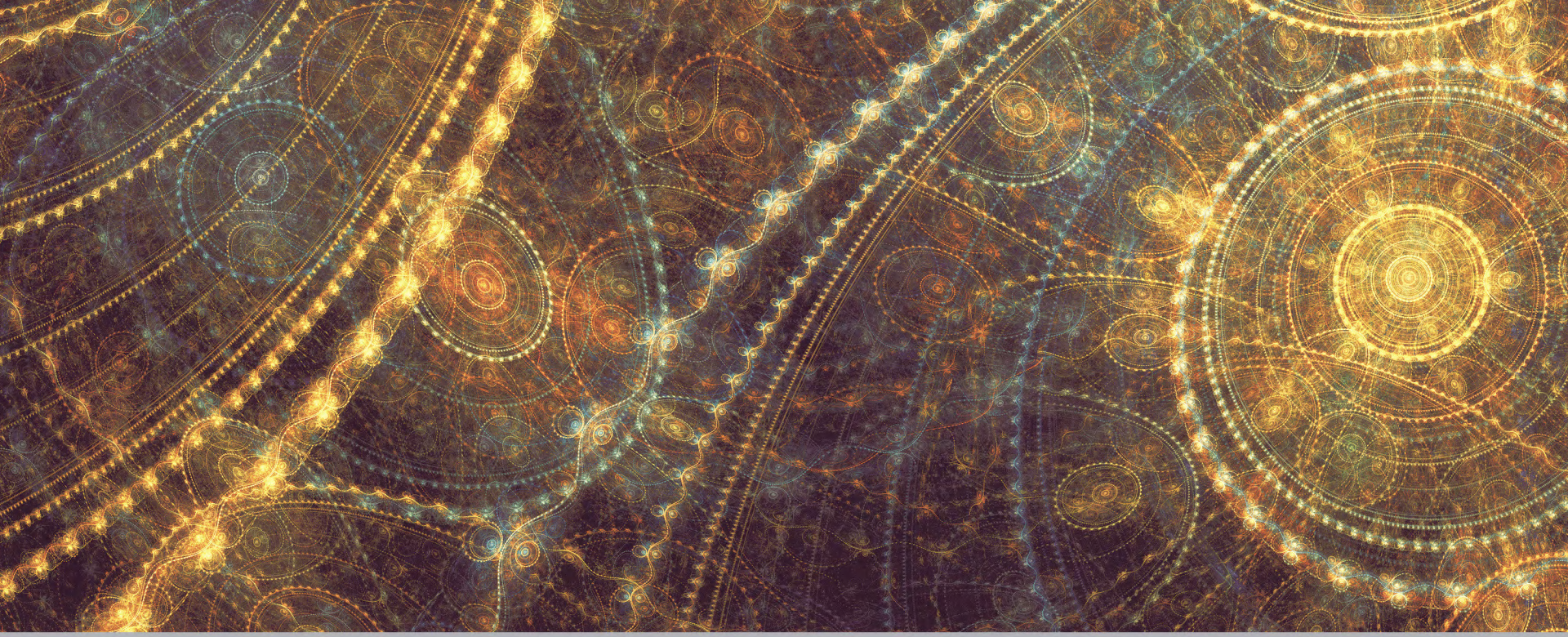

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Edited by Mirsad Hadžikadić & Liz Johnson

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TABLE OF CONTENTS

PSO

Editors & Editorial Board

Editor's Letter

The world we live in is unpredictable, surprising, fast changing, challenging, connected in unexpected ways, and often extreme. In other words, the world is complex. Such a complex world requires government policies that are measured, thoughtful, comprehensive, systemic, augmented, and pre-tested to the extent possible.

This is exactly why a journal like the Journal of Policy and Complex Systems is crucial for a more thorough understanding of the world we live in. Papers in this journal bring up issues of both theoretical and practical importance, quantitative and qualitative modeling, research and education orientation, as well as pragmatic and speculative nature.

In this specific issue of the Journal, the papers treat topics as diverse as integrating complexity theory in IR studies and applying complexity theories and techniques to enabling community dialogue, evaluating recommender systems on content diversity, evaluating courts of last resort, developing policies for climate change, resolving economic inequality and income distribution, and ending poverty.

This Journal is open to contributions from all fields of human endeavor, as long as such contributions include a problem description, a model suggestion and evaluation, and a policy recommendation. Alternatively, submitted papers might include either a theoretical or an educational treatment of complexity theory that has some policy implications.

We are looking forward to this process of building a community of scientists, practitioners, educators, and policy analysts for the benefit of us all.

Best regards,

Mirsad Hadžikadić
Editor, *Journal of Policy and Complex Systems*

El mundo en el que vivimos es impredecible, sorprendente, cambia rápidamente, desafiante, conectado de formas inesperadas y, a menudo, extremo. En otras palabras, el mundo es complejo. Un mundo tan complejo requiere políticas gubernamentales que sean medidas, reflexivas, integrales, sistémicas, argumentadas y probadas previamente en la medida de lo posible.

Esta es exactamente la razón por la que una revista como Journal of Policy and Complex Systems es crucial para una comprensión más profunda del mundo en el que vivimos. Los artículos de esta revista tratan temas de importancia tanto teórica como práctica, modelización cuantitativa y cualitativa, investigación y educación. orientación, así como de carácter pragmático y especulativo.

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En este número específico de la revista, los artículos tratan temas tan diversos como la integración de la teoría de la complejidad en los estudios de RI y la aplicación de teorías y técnicas de complejidad para permitir el diálogo comunitario, evaluar sistemas de recomendación sobre diversidad de contenido, evaluar tribunales de última instancia, desarrollar políticas para el cambio climático. , resolver la desigualdad económica y la distribución del ingreso, y poner fin a la pobreza.

Esta Revista está abierta a contribuciones de todos los campos de la actividad humana, siempre que dichas contribuciones incluyan una descripción del problema, una sugerencia y evaluación del modelo y una recomendación de política. Alternativamente, los trabajos presentados pueden incluir un tratamiento teórico o educativo de la teoría de la complejidad que tiene algunas implicaciones políticas.

Esperamos con interés este proceso de construcción de una comunidad de científicos, profesionales, educadores y analistas de políticas en beneficio de todos.

Atentamente,

Mirsad Hadžikadić
Editor, *Journal of Policy and Complex Systems*

我们所生存的世界是不可预测的、出乎意料的、快速变化的、富有挑战的、以无法预期的方式相连接的，并且时常是极端的。换句话说，世界是复杂的。这样一个复杂世界要求政府所制定的政策是经过衡量的、深思熟虑的、全面的、系统的、经过论证的、并且以尽可能的方式提前通过检验的。

这正是《政策与复杂系统期刊》至关重要的原因，它能增进我们对世界的全面理解。该期刊收录的文章汇集了具有理论和实践重要性的议题、定量和定性建模、研究和教育方向、以及实用性和推测性。

本期收录的文章聚焦多样化主题，包括将复杂性理论整合到国际关系（IR）研究中并通过复杂性理论及技术促成社区对话；评价推荐系统对内容多样性产生的效果；评价终审法院；为气候变化制定政策；解决经济不平等和收入分配，并终结贫困。

本刊欢迎各领域投稿，只要稿件包含问题描述、模型建议和评价、以及政策建议。或者，所提交的文章包括有关复杂性理论的理论研究或教育研究，且具有政策意义。

我们期待建立一个汇集科学家、从业人员、教育者和政策分析师的社区，以期造福所有人。

献上最美好的问候，
Mirsad Hadžikadić
编辑《政策与复杂系统期刊》

Integrating Complexity Theory in IR Studies

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Abstract

This paper offers a framework for the engagement of complexity theory in International Relations (IR) studies. Informed by the existing literature, this article adopts an inductive reasoning strategy to achieve the paper's aim. The associated literature suggests that a common trend focuses on aspects of complexity theory that may not motivate or influence scholars to adopt complexity in IR. Hence, there is a need to explain how complexity theory can indeed advocate IR scholarship. To fill this gap, the article has three sections. In the first section, a framework for understanding complexity is constructed; the second section critiques the existing published studies associated with IR complexity; and in the third, two examples are introduced to illustrate how complexity theory can successfully construct a framework to analyze IR phenomena at different levels. The article does not, however, promote the integration of complexity in IR studies without exploring potential challenges, particularly those related to the need of engagement of many unique concepts to IR studies.

Keywords: International Relations (IR) studies; complexity theory; self-organization, foreign policy; small states; reductionism

Integración de la Teoría de la Complejidad en Estudios de IR

Resumen

Este artículo ofrece un marco para la participación de la teoría de la complejidad en los estudios de RI. Basado en la literatura existente, el artículo adopta la estrategia de razonamiento inductivo para lograr el objetivo del artículo. La literatura asociada sugiere que la tendencia común se centra en aspectos de la teoría que pueden no motivar o influenciar a los académicos para que adopten la complejidad en las RI, por lo tanto, es necesario explicar cómo la teoría

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de la complejidad puede defender la erudición de las RI. Para llenar este vacío, la metodología del artículo se compartimenta en tres secciones. En el primero, se construye un marco para comprender la complejidad; la segunda sección critica los estudios publicados existentes asociados con la complejidad de las RI y en la tercera, se introducen dos ejemplos para ilustrar cómo la teoría de la complejidad puede ser una elección exitosa en la construcción de un marco de comprensión para analizar los fenómenos de las RI en diferentes niveles. Sin embargo, el artículo no promovió la integración de la complejidad en los estudios de RI sin explorar los desafíos potenciales, particularmente aquellos relacionados con la necesidad de involucrar muchos conceptos únicos en los estudios de RI.

Palabras clave: Estudios de RI; teoría de la complejidad; autoorganización, política exterior; estados pequeños; reduccionismo

在IR研究中整合复杂性理论

摘要

本文提出一个框架，用于研究国际关系（IR）研究中的复杂性理论。基于现有文献，本文采用归纳推理法。相关文献暗示，研究趋势所聚焦的理论方面可能不会激励或影响学者在IR中采纳复杂性，因此需要解释为何复杂性理论能促进IR文献。为填补该研究空白，本文的方法论分为三部分。第一部分建构了一个用于理解复杂性的框架；第二部分批判了与IR复杂性相关的现有文献；第三部分介绍了两个实例，以阐明在建构一个从不同层面分析IR现象的解释框架时，复杂性理论如何能成为一个成功的选择。然而，本文认为，需要探究潜在挑战，尤其是那些与“需要将许多独特概念纳入IR研究”相关的挑战后，才能将复杂性融入IR研究。

关键词：国际关系研究，复杂性理论，自组织，外交政策，小国，还原论

Introduction

After almost a century since its emergence, the study of International Relations (IR) continues to attract different methods and theories to analyze, explain, and understand associated phenomena. Constantly evolving and dynamic international politics has persuaded scholars in past decades to search for new and more compelling approaches, including the possible engagement of complexity science. The associated terms differ in the literature and among scholars, and complexity, complexity theory, complex system, and complex science are employed interchangeably. In some instances, scholars have argued that there is "neither a single science of complexity nor a single complexity theory exists yet" (Mitchell, 2009, p. 14) and have favored using the terms "complexity" and "complexity thinking," while others have cast doubts "about the contribution complexity theory could or could not make to theory and practice" (Eppel & Rhodes, 2018, p. 949). Despite the varied positions, the literature has witnessed considerable publications of complexity theory and its applications in many different disciplines.

Published papers and books strive to apply complexity to IR. Studies have focused mainly on substantive areas and in some instances have looked at special cases of complexity theory and attempted to apply it to IR to establish a generalized conclusion. The broadness of complexity theory necessitates answering epistemic questions regarding the way and the extent to which complexity theory can be engaged effectively. This challenge, as explained in this paper, no doubt maintained a gap in the body of the knowledge on how complexity can be used to add invaluable insights if/when it is included in the analysis.

In attempting to fill this gap, the paper proposes a novel approach on how to introduce complexity theory into IR studies by dividing it into three sections. The first section establishes an epistemic framework for understanding complexity by giving attention to areas perceived as most relevant to IR. The second section provides a critique of the existing associated literature with a focus on where and how IR literature has considered complexity. In the third section, two examples are introduced that explore complexity in IR. These examples demonstrate how new insights through complexity theory can improve our understanding of IR phenomena. The paper, however, makes it explicit that the adoption of complexity is not without challenges and in this regard, several limitations are highlighted and briefly discussed.

A Framework for Understanding the Complexity Theory

The ontology and epistemology of the complexity theory is centered on the observations and the study of dynamic systems. Such systems are characterized by their sensitivity to initial conditions and their constant evolution and emergence, resulting in the formation of nonlinear structures

(Black, 2000, p. 521). Nonlinear interactions of the components of a complex system delimit, if not eliminate, the possibility of prediction on which realists (rationalists) center their scholarship (Bousquet & Curtis, 2011, p. 51).

Initial conditions are those variables that existed at the time when the dynamic system moved from one status into the other, for example, the change of world order, shifts in the balance of power, and governing regime change. In dynamic systems, initial conditions do not exist independently, but emerge from the constant evolution of each system. During this process, conditions act as independent variables at the initial stage and their interaction/engagement with different system components result in adjustments until the system enters a new equilibrium. Differences in the quality/values (or both) of the initial conditions play a vital role in determining the future of the newly emerging properties of the system (Kavalski, 2007, p. 441).

The change of the initial conditions in the dynamic structures is not like those seen in the static systems. In mathematics, for instance, the linear $y = x + c$ and/or the nonlinear $y = x2 + c$ functions enjoy boundary (not initial) conditions, which helps extract the function value for any applied x. No matter how many times x is applied, the function values (y) can be known and a representing graph of the relation can be drawn. In other words, for a particular x, a particular y is available, and it is, therefore, predictable. In the dynamic system, this is not the case, since governing initial conditions will change and there is no guarantee that for a particular x, the corresponding y will have a particular value. The emergence of new conditions forms additional boundaries and results in new patterns of relations, hence shifting the system into a different order (Knoespel, 1991, p. 116). In such a case, the nature of the nonlinearity will leave almost no option for prediction. In other words, nonlinearity in a static system differs from a dynamic one in terms of the essence of the system's behavior and predictability of outcomes.

With unique collective behaviors and properties, a complex system moves into a new state called emergence. This explains the change of state and the nature of the current system as compared to the previous one (Batterman, 2010, p. 1031). The associated process is called evolution, which highlights the ability of the system to adapt to the surrounding environment. For a system to survive, it must undergo constant changes, allowing for a semi-cyclic adaptation to take place (Geyer & Rihani, 2010, p. 43). It is "semi" because during constant interactions between the system components and the surrounding sphere, new inputs infiltrate, resulting in offsetting/changing the initial conditions. Therefore, new inputs become new outputs; neither one is like the previous one. The process continues until the system enters a new level of equilibrium where a new wave of cyclic changes begins.

Understanding these concepts mandates the expansion of the scope of studies by including different disciplines such as biology, environmental

studies, sociology, management, mathematics, and chemistry, among many others (Burnes, 2005, p. 74). Additionally, fundamentals of complexity suggest that complexity theory can provide a framework that bridges different disciplines and thus can be regarded as a theoretically informing interdisciplinary platform. IR is an interdisciplinary area of study that is naturally linked to different discourses in order to analyze, explain, and understand events and the associated phenomena.

Among complexity theory's fundamental concepts is the nature of the complex system. The existence of the complexity is neither incidental nor accidental. Objective evolution of the system is in isolation to the human conscience, although humans, as rationally thinking agents, are not isolated from the system itself. The evolution of the system, which is influenced by the surrounding factors, may bring the system to the verge of disorder or chaos (Doll, 2008, p. 184). In the language of complexity theory, chaos is not the status of disorder, randomness, or confusion understood in conventional way, but rather an "orderly disorder characteristic of the systems" (Hayles, 1991, p. 1) and describes different types of order that rely on the previous status of the system (Knoespel, 1991, p. 116).

Complex systems differ from complicated systems and their differences are based on types, not degree (Poli, 2013, p. 143). Complicated systems are subjectively constructed and enjoy definite boundaries, allowing each system to behave in a controlled manner. An example of a complicated system is a computer program. Computer programs are human-made platforms with well-defined functions, algorithms, capacities, and limitations. For an ordinary user, they may seem complex; for experts in the field, they are not. No matter how and to what extent such programs are ramified, their boundaries are definitive. Comparatively, the complex system objectively exists/has been formed, although its emergence is not immune from subjective factors, and the system is infinite and/or constantly changing its boundaries. Constant changes of the quality of relations of the complex system components (attributes) give the system a property analogous to those observed and studied in the social science fields.

In a complex system, newly emerging characteristics are not necessarily contrary to previous ones; they can be integral and compatible, even if they are different. There is no perfect reincarnation of the previous structures, relations, or entities that highlights the differences between the quality of the new and the previous status of the system. The system components and their interdependence relations have non-localizable connections; the produced differences, however, are subject to the system's tendency to interiorization (the amalgamation of processes constantly responding to the environment) by known and unknown factors (Deleuze, 1994, pp. 183, 256), and since the system is constantly subjected to the influences of the external conditions, reproduction and repetition of the same components and relations are less possible (Deleuze, 1994, p. 256).

The tendency to interiorization helps the system to reorganize itself, particularly when it is on the verge of chaos. This major property features a self-organizing, self-regulating, or self-governing process. It modulates spontaneous order and events, and the quality is reflected in the ability of the system to respond to unpredictability and to provide a "counter-order" to potential chaos (Smith & Jenks, 2006, p. 253). The latter emerges from the interaction of the system's entities, whereby its ontological changes (Kavalski, 2007, p. 439) render a combination of pure natural process, outcomes of human actions/choices, role of institutions, governance, and many other known and even unknown entities (Barry, 1982, p. 3). The unknown entities might be problematic, as they add ambiguity to any theoretical or conceptual framework that considers the concept of self-organizing in their analytical model. This ambiguity has encouraged some scholars to critique the self-governing phenomenon, describing it as the Gaia hypothesis. They have based their critique on the consistence of teleological patterns that promote the ends as proof of its existence without presenting concrete causality logics (Lenton, 2001, p. 494). Another critique is based on the notion that social realities, which form an important part of the political realm, consist of a substantial level of control by humans and institutional agencies exhibiting organizational properties in addition to the self-organization ones. Hence, in politics, evolution and emergence are not purely objective or spontaneous phenomena. This adds complexity to the theorization of the complex system (Wight, 2016, p. 65).

The ability of a complex system to adapt and adjust reinforces its self-organizing capacity (Kavalski, 2007, p. 440). Adaptation and evolution enjoy a circular relationship as both are exposed to and influenced by the environment (Morçöl, 2012, p. 43). Adaptation causes different interdependent entities to move from one status into another and opens the way for the selection of conditions and attributes to maintain the system's state or move into a unique one that maintains its stability.

Adaptation is an important component of what is called Complex Adaptive Systems (CAS). It is a model or type of regime characterized by its ability to constantly adapt to external factors and newly emerging conditions. Although it is exposed to a wide sphere of the whole complex system, CAS is a special case of it. Constant evolution and adaptation are limited to the quantity and quality of information fed into and conditions influencing the system, apart from the length of the time associated with this process (Rihani, 2002, p. 8). CAS is also a special case because it is an agent-based model. Examples of agents in the context of IR include powerful leaders, influential groups, lobbies, and certain institutions involved in the state's foreign affairs.

Beside CAS, complexity theory recognizes the importance of other subsystems or regimes such as chaotic, orderly, and other organized patterns. What makes CAS special for this paper is its association with political phenom-

ena in areas such as policymaking and related decisions, the emergence of domestic and international governance, and the attempt by groups of states to design and implement integration projects, among many other issues. In addition, an advantage of engaging CAS in IR studies is that the model can help us reconfigure the role of the agency that is in constant interaction with the structure. It diagnoses its relations with the structure by identifying the role of rationality and cognition in the whole system through feedback loops, for instance. It, therefore, opens the way to integrate macro to micro levels of analysis by reducing the compatibility problems among different levels (Buckley, 1998, p. 79). CAS is included in broader discussions in this paper in another section.

Complexity theory can offer a framework that challenges conventional thinking. Its ability to include many disciplines that seem remote from each other can help expand research epistemology and reasoning about the phenomenon. This, however, is not without challenges, since for scholars, the engagement of many disciplines may seem unrelated to their area of knowledge and by extension, their comfort zone.

Where and How Complexity Theory is Positioned in IR Literature

Engaging complexity theory in IR studies is relatively new. In the last two decades, there have been a few attempts to include it in the list of theories in this discipline. The main synthesis among a discernible ratio of these studies is their focus on the nature of the international system and the attempt to reconfigure its complexity by disproving reductionism as being sufficient to explain its behavior; importantly, they emphasize the system level in their analysis (see, e.g., Clemens, 2013, p. 205; Cudworth & Hobden, 2010, p. 400; Jervis, 1997, p. 12; Scartozzi, 2018, p. 129). In addition, some studies have envisioned the international system as a CAS and upon this ontological and epistemological assumption, analytical and theoretical frameworks have been constructed (Holloman, 2008, p. 288; Scartozzi, 2018, pp. 109-130). Other studies have introduced complexity and described it as a main path towards the "fifth debate" in IR, a paradigm that challenges the dominant rationalism and linear thinking in favor of nonlinearity. This paradigm also emphasizes the interdependence of different agencies and their surroundings (Kavalski, 2007, p. 445).

In line with the above, this section focuses on three areas extracted fro-m the literature. The first is ontological, which looks at the nature of the international system in the context of complexity theory; the second critiques the literature associated with IR studies and CAS; and the third section attempts to draw some conclusions based on convergence between regime theory and complex theory as the former seems to be the closest attempt to engage some of complexity concepts in IR scholarships.

Reconfiguring the International System Beyond Anarchism

The emphasis on the nature of the international system in the context of the

complexity theory may have gained the most attention by scholars who have attempted to use it in their IR analysis. The overarching approach contrasts and/or compares the anarchism of the international system governing relations among nations with system complexity (Kissane, 2014, p. 203). Beyond the conceptual and introductory levels, the content of the comparison, however, is problematic, since the ontology of complexity theory considers complexity as all-inclusive. Therefore, anarchy, like many other properties, is merely part of it and at best is a subsystem that includes a set of attributes that assist us in understanding a specific area of study: in this case, international politics (Açikalin & Bölücek, 2014, p. 33). Such ontology, however, is advantageous in the sense that it helps us develop insights, suggesting that anarchism itself is not rejected by the complexity approach. Rather, it is included in it, and in some cases, international anarchism is reconfigured through it, although from a different stance than those common in the literature of the realism.

Cesare Scartozzi's (2018, p. 129) analysis, for example, established the self-governing property as another ontology of the anarchic complex international system and in this way, added such "ontology" to the balance of power concept, whereby the main character explains the driver of the anarchic system envisioned by neorealism (Waltz, 1979, p. 103). Self-governing is active in a world where there is no central government in charge of its affairs; however, the available literature thus far has not made a reference to the nature of the relation between such phenomenon and the balance of power. The main challenge facing such an approach is the lack of material proof; hence, it leads to reliance on observation of the results of the patterns of relations among states before drawing a theory based on the outcomes of relations. This may open the door for criticism because it emphasizes teleology in the analysis (Wight, 2016, p. 65).

Another challenge introduced by CT to rationalists and particularly realists (in the context of an anarchic system) is that delimiting predictability is problematic, particularly in foreign policymaking. Realists may argue that although the balance of power in an anarchic system may not produce a perfect calculation, it may still offer "better orderly error than complex truth" (Galbraith, 2001, p. 68).

Beyond anarchism, the literature of complexity theory offers many other systems, such as rhizome, constant evolutions, composite, and non-state actors' (NSA) interest-based regimes, among many other known and unknown systems. Complexity theory includes all these without claiming that it is an agglomeration of all; rather, it includes them among many others that may not yet be known to scholars. Such inclusion reinforces a complexity approach to IR by converting it into a highly interdisciplinary area of study and by extension leaves no space for reductionism. In such a reality, therefore, it is expected that IR studies will have noticeable shifts, not only in terms of the studies' ontology and epistemology, but also in relation to their methodologies.

A rhizoidal system, for example, introduces a unique perspective to IR. The international sphere is analogous to a rhizome, an entity characterized as having no start, no end, and unclear boundaries and consisting of many sub-entities that might be connected at any point and at any time. New connections are constantly emerging, leading to the formation of unique entities. Such emergence can be vertical, horizontal, and/or in any direction and its dimensions are possibly determined only at some point in time since it will change at other times, leading to the formation of many layers of plateaus and branches (Deleuze & Guattari, 2004, p. 23). Applying this concept implies that the rhizoidal nature of the international system maintains its openness and constant interaction. The variants in dimension may not necessarily imply the generation of parts like the previous, as some aspects of the system is self-similar, while others are not (Mandelbrot, 2013, pp. 146-148). Therefore, the latter may take different forms or shapes that highlight certain properties of the system and/or results from the impacts of the surrounding environment or even for unknown reasons.

The nature of a rhizoidal system undeniably leaves no space for ontological reductionism. The expansion and evolution of a rhizome complex system will produce new properties; in IR, this includes the emergence and growth of new global political players. Constant emergence will leave no place for not only ontological but also methodological reductionism to tackle the phenomenon, apart from reducing reliance on normative based approach/es to explain politics (Olssen, 2016, p. 140).

In the composite system, the picture seems clearer. Entities of this system are neither scalars nor vectors; the sum of their effects is not equal to the whole, and it can be more or even less depending on the direction of their effects and the surrounding conditions. If entities are modeled in terms of vectors, the immediate consequence is the adoption of the superposition principle (Arrighi & Dowek, 2013, p. 130), which is a linear Newtonian notion that explains the sum of the magnitude of entities that are not necessarily interacting with each other. Static linearity and the lack of interactions are rejected by a complex system, as explained previously. The example of combining water and sugar can explain how methodological reductionism lacks the ability to explain a composite system at its simplest level.

Combining 100g of sugar with 1kg of water produces a mass of 1.1kg, while adding 1L of water to 0.1L of sugar results in a volume of a solution that is less than 1.1L. The reason behind the latter's outcome is due to the dissolution of the sugar in the water. Yet, the density of the solution is greater than the density of the water. The Newton superposition principle, which forms an important aspect of reductionism, in this case failed to explain a simple case in a composite system. And when the system consists of many entities, of which many/few might not be known, then it can be logically concluded that complexity theory rejects reductionism.

Rejecting reductionism particularly when defining the international system might seem attractive in the sense that it promotes the adoption of holistic approaches. However, such an assumption may face tremendous challenges in several areas important to IR studies, mainly at the methodological level. A rhizoidal system's layers, for example, are not only hierarchical, which has vertical patterns, but also consists of horizontal layers, which may include government, charismatic individuals, and NSAs, such as civil societies and NGOs, in addition to other state players (Harrison & Singer 2006, p. 26). The attempt to engage complexity theory, therefore, becomes a taxonomic impediment, which ultimately makes it difficult to capture the most appropriate units and variables necessary for the analysis.

The International System as a CAS

Some studies (see for example Alker, 2008, p. 327; Cudworth & Hobden, 2010; Hobden, 2016, p. 177; Kavalski, 2007; Scartozzi, 2018) have attempted to model the international system and its interacting factors as a CAS. The international system includes material power, state actions and behavior, human and other agencies' roles, domestic to external structure relations, and global governance, among others. The studies' main ontological and epistemological assumptions are centered on the world being a CAS, in which there are constant evolutions and interactions among its different components. At the state level, the evolution that highlights a neo-Darwinian approach to IR may depend on objective and subjective factors. The first may include state material limitations, such as an abundance of natural resources, military power, geographical location, populations, etc., while subjective factors comprise mainly the quality and levels of available competency of state institutions and individual agencies.

Envisioning the international system as a CAS implies that this system's environment is part of a larger environment (Olssen, 2016, p. 153). This is because CAS functions on two levels of interactions: inter and intra. The first signifies the quality and quantity of repeated cycles of interactions between CAS and its surroundings. Such exposure updates and helps evolve the system constantly, for instance, by feeding it with information, new events, new policies, impacts of other systems, and so on. The intra level is a localized fluid of CAS energy. More specifically, it consists of all attributes and actions taken within the CAS's boundaries and depends on the quality of functioning agents and institutions within the system's environment (Buckley, 1998, p. 78).

The antithesis to this suggests that envisioning/modeling the international system as CAS might be problematic. This is because CAS's interaction with the adjacent environment suggests that it is a smaller part of a surrounding environment; yet not every complex behavior can be labeled as CAS. In other words, CAS is a special case of a complex system (Chen & Wang, 2009, pp. 188-189) and since the international sys-

tem is a complex structure, a methodological question arises as to how CAS helps us understand international political phenomena.

Not only methodological but also ontological questions emerge. CAS is well known in areas of agent-based modeling studies (Kavalski, 2007, p. 447). In the language of social and political interactions, CAS may reduce the debate to the agent-structure level and, by doing so, influence the outcomes of analysis by the inclusion of ontological reductions. Such "tendency would be highly contentious within the broader confines of CT" (Cudworth & Hobden, 2016, p. 172; Olssen, 2016, p. 140). An example is when a state's foreign policy (FP) sensitivity to global changes is frequently observed. If the FP is highly self-adjusting and actively responding, then CAS can act as a theoretical framework for such FP analysis. However, it is important to recall that such a case still limits the scope of studying the state IR to some extent.

One of the main advantages of including CAS is its ability to bring the meso level into the argument. Interactions by agents are not necessarily circumscribed by the institutions within a state. Its interactions consider the role and impact of international organizations and other states' FPs (Bousquet & Curtis, 2011, p. 54). Such multidimensional interactions almost eliminate the dividing lines among individual, state, and system levels. Such elimination does not, however, preclude distinctions of emerging properties at each level. Interactions continue between the newly emerging patterns of properties of the different levels; therefore, inference cannot be based on a single level (Kavalski, 2016, p. 6).

This unique approach offers a new epistemology to IR research. However, the antithesis to this can be observed when there are minor or slow changes in the patterns of political behavior: for instance, states that attempt to craft FPs with their main objectives of maintaining their status quo through minimal interactions.

In both cases, analyzing and explaining state behavior by adopting CAS as a framework might be a challenging task. This includes both active and passive state interactions. The reason is that such analysis requires the constant collection of supporting evidence and data, which may not be available all the time. Having minimal emphasis on initial causes may encourage criticism due to scholars being teleological (Woodfield, 1976, p. 1).

Convergences Between Regime Theory and Complexity in IR

Stephen D. Krasner (1983, p. 1) defined the international regime as "principles, norms, rules, and decision-making procedures around which actor expectations converge in a given issues-area." There is no single universal regime, but rather many sub-regimes that form a regime that is more than the sum of its parts. Complexity theory establishes a framework aimed at capturing those governing patterns of behaviors of states and by this, the regime becomes a causal intervening and/or constitutive

independent variable under which the political phenomena can be analyzed and explained (Krasner, 1983, p. 21). The regime may help establish a certain level of cooperation among nations, although not every cooperation initiative results from a regime. Cooperation and/or competition may emerge for a variety of reasons, and even if the regime enables some order, regime is not a replacement for the latter (Haggard & Simmons, 1987, p. 497).

Established order by the regime, as some scholars have argued, is an alternative to hegemonic stability theories (Hasenclever et al., 1997, p. 89) and its explanations, as related to stability in terms of cooperation, can serve as an alternative to those seen in theories that favor institutional liberalism. In other words, it is a third way of understanding international governing systems beyond classical thinking. Although this attribute, ontologically and epistemologically speaking, might promote an understanding of regime theory having self-organizing/governing phenomena, other features of regime theory can tell different stories.

As explained, the self-organizing property exists objectively and becomes active under certain conditions, while a regime is a governing system that is influenced to some extent by the input of powerful institutions. An example of this is the implementation of Chapter VII of the United Nations (UN) Charter. This chapter authorizes the UN Security Council to use power, including forming an international coalition "to maintain or restore international peace and security" (UN, n.d., para. 4). The chapter was activated after the Iraq invasion of Kuwait in 1990.

Furthermore, a regime is a framework that explains the system level of analysis, a level that is considered by complexity theory, which recognizes no boundary between levels. Dedicating regime theory to the system level leaves regime theory, in terms of the role of the influence of the domestic structure, in a critical position, as some scholars have argued (Haggard & Simmons, 1987, p. 513). A negating point could be that Krasner's definition of the regime included decision-making procedures that are, apart from international institutions, linked to the foreign policymaking process, an area that falls to some extent within the domestic political structure.

A regime, therefore, is merely a part of the complex international sphere and at best can be described as another special case of it. Its scope is limited to a certain area and a specific system. It has shared attributes with complexity theory; however, it may indicate an attempt to engage complexity in a specific way in IR, for example, through the adoption of a theoretical reductionism and emphasizing systems and the evolution of governance. Divergence between theories may suggest that it is not an alternative theory or a light version of complexity theory, but rather a focused theoretical framework on certain aspects of complexity philosophy. What motivates the inclusion of this theory in the current paper is its attempt to adapt and engage some complexity concepts

in IR. With such convergence, it might suggest that complexity theory is another and like CAS, a special case of a complex system.

Introducing Complexity Theory in IR: Two Examples

Reviewing the complexity IR literature helped me develop an important observation of the absence of enough applications and examples, including examples that could simplify the engagement of complexity theory in IR analysis. Examples and applications of CT to IR in published studies suggest a common trend characterized by emphasizing a particular aspect of CT and then attempting to apply it to an international event or vice versa, i.e., IR to CT (see for example Bousquet & Curtis, 2011, p. 56; De Roo, 2015, p. 360; Hobbs, 2015, p. 252; Kavalski, 2016; Shine, 2015, p. 172). The dense language of complexity may have encouraged scholars to adopt conceptual metaphors in explaining and applying complexity theory (Bousquet & Curtis, 2011, p. 56). Although this might be advantageous in the sense that it clarifies complexity theory's concepts and their applications, it is possible that it undermines its authenticity. It raises an epistemic concern about the extent to which CT can be helpful in offering different and distinct insights to those introduced by other theories.

To overcome such concerns, two examples are considered in this section. The examples explore a broader application of CT-IR than those observed in the literature. The main objective is to expand the knowledge of scholars and IR students by aiding them in establishing epistemic frameworks that consist of CT in IR studies.

The examples focus on two well-known areas in IR. Supported with empirical evidence, the first example explores small state behavior in the international arena and in the second example, a framework is established to show how FP can be modeled as a CAS.

The Example of Small States' Behavior, Adaptation, and Responses to International Events

In his study on international relations of small states, James N. Rosenau (1983, pp. 22-26) generated a theoretical perspective that foreign policies of small states are responsive and adaptive in nature due to their limited capabilities. Rosenau concluded that the size of small states is a variable that portrays the causal factors' and material ontologies' influence on each state's policy behavior. The evidence presented in his study centered on the observation that leaders involved in policymaking in small states seek to formulate policies that promote integration among the nearest or internal group of states. Additionally, leaders tend to maintain certain policies that enhance and strengthen the autonomy of the state's foreign policies by following strategies of constant adaptation of international issues.

Rosenau, among a few other scholars (see for example Beyer, 2006, p. 306; Coaty, 2019, p. 42; Goetschel, 1998, p. 23), brought the adaptation of small states as an important methodology for

the state's survival. This behavior lies at the heart of CT. In a complex system, small states are sensitive interdependent entities with the external environment. Their interdependence moves them from one status into the other as a direct result of acute new inputs from the adjutant environment. This implies alterations ranging from minimal to significant in the state's FP.

From the realists' perspective, such alteration is a direct consequence of the state (which may have little options) having a rational choice to maintain its survival. An example of a significant level of adjustment is when a state bandwagons as a strategy. The realists' reasoning might seem easy and convincing, which is not surprising due to their heavy reliance on linearity. However, CT, which does not necessarily reject such reasoning, adds that adopting such strategies can be related to more sophisticated reasons and be based on many grounds.

Some of the reasons may become clear after a while, while others may be related to those mechanisms that highlight the ability of the state to self-organize; in the context of complex systems, some of these mechanisms continue to be unknown.

But analogous to the realists' view, adaptation is a rational choice for small states that have minimal options. Although the literature focuses on how CT explains changes, there is less emphasis on causalities. This might be related to reasons such as the tendency to over-determine, where different interpretations provide convincing causes (Reichenbach, 2016, p. 67), and to prevent complexity theory from possible accusations of emphasizing teleology (Wight, 2016, p. 65). Complexity theory does not undermine the validity of the these claims, but rather (a) explains the fact that such claims highlight known causes, although unknown causes are (hopefully) still to be extracted; (b) shows that adaptation is an objective behavior of the state that forces policymakers to adhere in isolation of their will and consciousness and is reinforced by constant feedback; and (c) adds that state adaptation is carried onto the international system level. It does not, however, exclude the individual level, for instance, by including the FP process and by this, making it possible to include different levels of analysis.

"State branding" as a FP crafted by the main policy actors in Qatar since 1995 materializes the issue above. Leaders of this small state recognized its limited hard power and ability to leverage its influence (Ulrichsen, 2014, pp. 38-40). By relying on its booming energy-based economy, supporting Arab exiles such as the Egyptian Muslim Brotherhood members and even hosting intra-Afghan talks between rivalries and with the United States (Qazi, 2020), Qatar emerged "into a regional power with international reach" (Ulrichsen, 2014, p. 168). With careful reading of the international political map, the small state's FP witnessed a major adjustment since the change in its leadership in 1995.

This change set a new initial condition. As such, by comparing Qatar's

influence today with its status almost quarter of century earlier, researchers can record the butterfly effects that range from Doha to becoming an observer member of the Latin American and Caribbean Parliament (QNA, 2019)! Supported by their powerful Western alliance, such as the United States, Qatar's leaders post-1995 crafted their visionary strategic FPs at the international level. Domestically, changes can be seen through the country's transformation to first class infrastructure, hosting regular international summits, among many other mega scale projects (Kamrava, 2015, p. 9).

On the agent-domestic structure level, the leadership in Qatar is free from many restrictions. In this stable small state and throughout its history, a normative culture of obeying the prince became dominant. Actions and feedback are not based on criticism or opposition (Kamrava, 2015, p. 18). This may have allowed the country to expand the domain of actions at the international level and ultimately help the state evolve to the next level. Furthermore, despite its size, the country has successfully implemented policy decisions to establish world-class institutions, universities, global studies centers, etc.

A small state is a relatively confined unit in comparison to big states. Its macro actions are micro in relation to big states. However, and against the background of CAS explained in this paper, the smallness of the state as ontology is problematic when it comes to investigating the distinctions between its interactions internationally from those at the domestic level. The separation between environmental and internal loops, for instance, becomes complicated as a direct consequence of the confinement.

An active IR of a small state may help the investigation determine whether its behavior can be modeled as a CAS. A state government is the action unit; its adaptation to external reality helps mitigate its impact and allows it to capture opportunities. Filtering and using information may be necessary since the scale of demand is low, and the information that finds its way to policy-making ultimately leads to a change of behavior. If a small state's behavior is not CAS, such a framework therefore becomes normative. The confined size of a small state allows complexity theory to diagnose and treat it merely as an organ in world realities of relations.

Foreign Policy Formulation and Implementation as a CAS Example

In alignment with the previous example, the state FP's process can be modeled as CAS. Such a modeling is not particular to a state's size; as explained previously, it is a special case of complexity theory that captures specific patterns of behavior. The main advantages of engaging CAS are (a) it helps develop a framework beyond those conventionally adopted in the subject area; (b) it offers a platform to diagnose the state policy level of sensitivity and the policy quality, for instance, through feedback loops; and (c) it helps capture the essence, the so-called attractor of the FP process, of the particular state.

Even though the international system is anarchic, composite, or rhizoidal, a CAS model can explain the extent and nature of state interactions with the external sphere. For example, the model can test the state's FP decisions (domestically formulated) through constant feedback loops to show the differences between previous and current policy outcomes. Successfully formulated and implemented FPs will reinforce the position of policymakers. This is called positive feedback, while the negating scenario is negative feedback (Webber, 2002, p. 84). Both cases are enlightening. The first indicates an effective a priori reading of the surrounding reality, while the second helps diagnose gaps in the policy and therefore encourages the listing of lessons learned for future actions. Thus, changes in future policy depend on the competency of analyzing events in an FP system. As such, successful changes constantly transform and reform the FP system.

An example from the contemporary era of how FP can be CAS is the United States' adoption of transformational diplomacy after the September 11 terrorist attacks. The new policy system included almost all CAS properties. Adjustments, for instance, consisted of repositioning available resources to critical emerging regions such as the Middle East and certain parts of Africa, readjusting existing resources in the State Department to understand and cope with the new realities of further exposing posted diplomats to the public in countries where they are serving. In addition, emphasizing public diplomacy through the establishment of different platforms and initiatives gained more importance in marketing the FP (U.S. Department of State, 2006). To ensure such initiatives and actions meet their objectives, the State Department rigorously established a feedback loop system and lessons learned database to improve the quality of diplomacy and enhance its effectiveness overseas. Extensive reliance on soft tools helped to centralize and share information effectively. This was not only dedicated at the level of diplomats but was extended to include interactions and services to millions of citizens virtually, thus reaching many people in areas and cities where U.S. missions are not available, apart from saving tremendous costs (U.S. Department of State, 2006).

Another example of CAS-FP comes from the Arab-Israel history of conflicts. The 1956 Suez Crisis and the tension in the following years, particularly between Egypt and Israel, can be modeled as a continuing butterfly effect that manifested in the 1917 Balfour Declaration (Schneer, 2011, pp. 319, 325), the 1948 war, and the establishment of the new state of Israel in 1949, among many other events and crises. These brought the concerned states to the verge of chaos by June 1967, when Israel formulated and implemented a FP of launching a full-scale attack against Egypt. The war lasted six days and created major and new realities on the ground for Israel and Arabs. Israel extended its control to include part of Syria, the Gaza strip, and the West Bank, apart from the Sinai Peninsula in Egypt. Similarly, a series of military operations led by Egypt from March 1969 against

Israel highlighted the beginning of crises, so called by the Egyptians as "War of Attrition," which lasted until August 1970, when both sides agreed on a ceasefire plan by U.S. Secretary of State William Rogers (Brecher & Wilkenfeld, 1997, pp. 284, 285). The crisis continued between the two sides during the no war, no peace period. It also included tremendous economic pressure on both sides. By October 1973, the two countries entered a new war.

Crises, in the above example, are intervening variables and on certain occasions led to war. In a study titled "Crisis, Conflict, War: State of the Discipline," scholar Michael Brecher (1996) reviewed papers related to wars and crises. The analysis suggested that although not all crisis and conflicts among countries lead to wars, environment-adjusting mechanisms tend to manage conflicts, many of which are concluded considering careful and rational calculations and other results from perceptions of the FP decision-makers. Brecher's collection and analysis of the empirical evidence suggest that constant complex interactions of the state with the external environment exposed its policy to a variety of constraints that found its way into the FP decision-making system. The quality of the filtered information and accurate reading of the FP makers can then play a vital role in deterring a matrix of options from which policymakers can choose that meet certain targeted values (Brecher, 1996, pp. 127, 129, 131).

The tit-for-tat game between Arabs and Israelis, particularly during the War of Attrition, highlighted a policy adjustment from both sides. Both countries gathered intelligence and attempted to have the first strike after learning a lesson from the 1967 war. The two sides also did not hesitate to include the world political environment—the Arabs with USSR and Israel with the USA (external loop of interaction). They also prepared themselves domestically (internal loop) by reengineering and psychologically shaping public opinion. These conditions added to Becher's findings and affirmed the applicability of CAS in the analysis of the relations between Israel and Arabs at a certain time in the history as it included all major components of CAS. CAS in this case can be envisioned as a model that explains the nature of the complex relations between all countries engaged in the conflict directly and indirectly. The distinctions between the FP strategies of the two sides may highlight two separate CAS models. Arabs adopted an active approach (strike), while Israel did not want to appear to be a victim. Israel chose to follow Prime Minister Golda Meir's perception over the army leader's rational calculations (Tsoref, 2018, p. 52), falling into a relatively passive position in the early part of the 1973 war, compared to Arab policy. The intelligent gathering (evidence) prior to the war might be of similar nature for both sides; however, reading and filtering the most relevant information differed depending on the competencies of agents on each side.

The CAS model explains that gathering and scanning the most appropriate information as an action is done

mostly at the state level, i.e., groups and individuals. In IR, seeking information is vital. However, not all available information is significant for a state. The chaos of information is highly challenging, particularly when there is a limited time to respond to an event. In the complex adaptive model, this stage is administered by the most competent and relevant units and individuals, e.g., the support staff and smart institutions. In the absence of high-quality institutions, this becomes a normative assumption.

Highly qualified agencies, according to the model, will present policy alternatives. However, the development of FP options is reinforced by feedback from previous policies, similar events, the outcomes of implemented policies elsewhere, etc. Feedback loops help adjust the policy to reflect the emerged realities surrounding the event. Feedback loops also provide constant evaluation for previous FP decisions. External (environmental) loops denote the state's level of exposure to external reality (i.e., political dynamics at the system level), while internal (domestic) loops are associated with a careful understanding of ever-evolving situations. Considering and including the most appropriate data in the formulated policy signifies the essence of adaptation. Breaking down the process, however, is not necessarily sequential.

Under uncertainty, CAS as an FP model allows us to make assumptions about the available parameters, variables, and constraints. This is a typical case for FP decision-making models. This has the advantage of listing anticipated/probable outcomes and consequences of each decision (Ostrom, 2007, p. 26). The disadvantage, however, is that assumptions may include biases and may encourage the reliance on heuristics. However, this is not a problem specific to the CAS-FP decisions model; it is common in others, including rational models (Jervis, 2006, p. 650). In other words, the CAS-FP model does not discount cognitive, systems, or even psychological factors from influencing the policy due to its reliance on human and institutional agencies during the policy decision-making process. However, constant policy adjustment as a direct consequence of positive and negative feedback allows the model over time to emerge into an intuitive device that can self-adjust and therefore enhances the policy quality and reduces the risk of being detached from reality.

The absence of an FP decision-making theory (Herborth, 2015, p. 101) is filled with FP models: for instance, unified rational actor, political bureaucratic, and actor-specific models. Models help us investigate the process that leads to the formation of the policy. The insertion of CAS in the family of FP models includes all those advantages explained in this paper. Although the model is not intended to provide policymakers with prediction, it helps reduce the risk of external realities through careful readings and mechanisms of policy preferences and selections and returns political transformation processes at the global level to the core of the policymaking system.

Conclusion

In this article, I identified and explained the compatibility of complexity theory in the IR field. More specifically, I aimed to clarify as to where, when, and mainly how to engage complexity theory in IR analysis and at different levels. The review of the associated literature highlighted a major observation that published papers have focused on substantive areas of complexity theory; however, an epistemic confine was generated by not exploring important aspects of complexity theory. The reviewed published papers missed a few fundamentals of complexity theory. This is highly important, as it may have ontological and epistemological consequences in favor of limiting engagement with complexity theory. Furthermore, this article made it explicit that complexity theory includes many concepts that are unfamiliar to IR. Complexity theory mandates an engagement of the interdisciplinarity of multiple levels and methods of analysis, which no doubt requires extra effort and skills to tackle and include in constructing any theoretical framework.

The inclusion of many interdisciplinary concepts does not qualify complexity theory as an agglomeration of many theories. Complexity as an approach starts with a main introduction defining its nature/essence, and when attempting to apply it to IR, there is a need to identify and explain how the international sphere is inevitably complex. A complex international sphere is not an external structure to the state; it includes domestic, external, and in-between structures. The immediate consequence of this is a noticeable advantage to the IR literature since it eliminates dividing lines between domains, the so-called levels of analysis. It enriches IR studies by allowing many causal variables in the analysis, even though this complicates the analysis and opens the way for further over-determination. Complexity theory rejects the trade-off of highly sophisticated analysis for the express purpose of introducing simplified approaches to understand phenomena.

Analysis in two examples in this paper demonstrated how complexity can reconfigure IR phenomena in unique ways. It is a new language for IR scholars. Crisis is a certain stage of the butterfly effect; adaptation, which plays an important role in emergence, is a mechanism that explains the quality of reading information by state individuals and institutions, which ultimately reflects on the state's FP. An additional implication is the anarchy of the international system, which is envisioned as merely a property of the complex international system in which war is a stabilizer event, since it represents the end of certain crisis! And most importantly, emergence suggests that complexity theory can continue to explain changes in world structure. Emergence will not restrict complexity theory's application to events in a specific era of the history, since its main ontological assumption is associated with the world's political structure constantly changing. It therefore enriches and adds many insights by distinguishing complexity from other IR theories, as it is applicable at all stages of history and not to a specific period of world order.

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Real-World Applications of Two Complexity Based Systems That Are Proven in Helping People in Communities and Organizations Come Together in Dialogue to Solve Important Complex Challenges Facing Them

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Abstract

The people in communities and organizations across the world are faced with an increasing array of difficult, complex problems. Complexity-based systems and processes need to be used in order to successfully investigate these problems and discover solutions. Diverse groups of people must come together in dialogue to create new, more innovative and sustainable ways to work and live together. Designing and guiding these conversations is challenging. Participants have the knowledge they need to begin devising new solutions, but they lack the process tools to engage in purposeful dialogue. Without an underlying process to keep conversations focused and on track toward solutions, conversations become diffused and chaotic. This paper presents two, proven complexity-based processes that enable the people to generate solutions to the complex problems facing them.

Keywords: Complexity, Complex Adaptive Systems, Process Enneagram, Strategic Doing

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Aplicaciones en el mundo real de dos sistemas basados en la complejidad que han demostrado ayudar a las personas en comunidades y organizaciones a unirse en un diálogo para resolver importantes desafíos complejos que enfrentan

Resumen

Las personas de las comunidades y organizaciones de todo el mundo se enfrentan a una gama cada vez mayor de problemas complejos y difíciles. Es necesario utilizar sistemas y procesos basados en la complejidad para investigar con éxito estos problemas y descubrir soluciones. Diversos grupos de personas deben unirse en diálogo para crear formas nuevas, más innovadoras y sostenibles de trabajar y vivir juntos. Diseñar y guiar estas conversaciones es un desafío. Los participantes tienen el conocimiento que necesitan para comenzar a idear nuevas soluciones, pero carecen de las herramientas de proceso para entablar un diálogo con propósito. Sin un proceso subyacente para mantener las conversaciones enfocadas y encaminadas hacia las soluciones, las conversaciones se vuelven difusas y caóticas. Este artículo presenta dos procesos probados basados en la complejidad que permiten a las personas generar soluciones a los complejos problemas que enfrentan.

Palabras clave: Complejidad, sistemas adaptativos complejos, eneagrama de procesos, acción estratégica

两个基于复杂性系统的实际应用：帮助社区和机构中的人们共同参与对话，解决其面临的重要复杂挑战

摘要

全球各社区和机构中的人们正面临越来越多的、既困难又复杂的问题。需使用基于复杂性的系统和过程，以成功研究这些问题并寻找解决方案。多样化的群体必须共同参与对话，创造新的、更创新的、可持续的方法来共同工作和生活。设计并指导这些对话具有挑战性。参与者具备最初设计新解决方案所需的知识，但缺少过程工具来参与有目的的对话。如

果没有一个潜在的过程让对话保持重点并向解决方案的方向发展，对话则会变得分散且混乱。本文提出两个已证明的基于复杂性的过程，这两个过程让人们能创造复杂问题的解决方案。

关键词：复杂性，复杂适应系统，Process Enneagram, Strategic Doing

Introduction

The world is besieged with complex problems. These are challenges that arise from multiple causes; thus, determining a "root cause" is difficult, if not impossible. Each complex problem is unique, and there are no simple pathways provided by history. There are also no clear solutions to wicked problems, and no solution is perfect or permanent. They can't be "fixed."

Climate change, the scourge of opioids, youth violence, infant mortality, etc., all represent complex problems. Complex problems that keep coming back and are not resolved are called wicked problems. Increasingly companies, government agencies, and nonprofit organizations are challenged by complex problems. Seemingly straightforward technical challenges, like moving a company to embrace digitization more quickly, become complex problems of managing complex human interactions.

The concept of wicked problems emerged from the field of urban planning in the 1960s in Rittel and Webber (1973).

Yet, while wicked problems cannot be solved, they can be managed. We can design new systems that generate better, more valuable outcomes. To do that, we need to engage our collective intelligence and manage the complexity of our conversations. We introduce two field-tested approaches to designing and guiding complex collaborations to address wicked problems. Both models emerged from "reflective practice" described by Donald Schon (1983).

Over a quarter century consulting career, Edward Morrison developed a complexity-based process called "Strategic Doing." This process forms complex collaborations quickly within a diverse group of community people. These collaborations are designed to launch experiments of new ideas. The discipline consists of a set of simple rules based on 10 skills of collaboration. By designing and guiding conversations with these rules and skills, participants can devise, test, and adjust new solutions to complex problems. In this way, they can quickly devise strategies to move forward (Morrison et al., 2019). Several hundred communities across the United States, Australia, Canada, and Europe possess Strategic Doing guides.

In his 35-year career as a chemical researcher and manager of several large chemical plants for the DuPont Company and another 25 years helping companies and other organizations around the world, Richard Knowles (2002) has developed other complexity-based tools and processes centered around the Process Enneagram©, a tool that bridges complex adaptive systems theory and practical application. People in organizations can use this tool to identify who and what they are and to see how and why things are happening as they are. They can see the whole and the parts of their complex problem and can open the patterns for success. This process of working together is called Partner-Centered Leadership (Knowles, 2020). Several hundred guides are spread around the United States and the world; many diverse organizations and cultures successfully use the Process Enneagram.

Both approaches use disciplined dialogue processes to bring people together so they can learn by doing. The two models share some important common characteristics. Both depend on creating an environment of civility and psychological safety. Participants are open and honest in their work. They treat each other with respect to promote listening, learning, and complex thinking and trust together. Both approaches enable participants to design a shared future. In the process, they share information freely, ask questions, and provide feedback. During their dialogues, people discover that they are making a positive difference and finding meaning in their work.

These processes accelerate and enable collaboration and link and leverage strategies and solutions. A new culture emerges as people learn to think differently, behave differently, and do work together differently. This new culture creates the basis for successfully addressing increasingly complex challenges. Both processes are fractal in nature. They are scalable; they have been used with groups of many different sizes ranging from just two to three people to groups of over 100 people. Finally, both approaches are cross-cultural. They have been deployed successfully in many different cultures.

Some Strategic Doing Stories

In 1993, Oklahoma City was struggling to revive itself using traditional strategic planning models. These linear, ponderous models were not working. The City was facing 10 years of economic stagnation, collapsing oil prices, and a serious bank collapse. City leaders called upon Ed Morrison to help them. He assembled a diverse core team and designed an approach built around open collaborations. They learned to work differently from the traditional ways. They relentlessly tested and explored many ideas to see what would work. They led by example. New investment started to flow into the City. While the terrible bombing set them back a year or so, they picked up speed and by 2000, $403 million in new investment had come into the City. The vibrancy of Oklahoma City continues to grow.

In another story, Morrison led similar successes in recovering an eco-

system, helping revitalize 18 distressed Kentucky communities, designing the Charleston Digital Corridor, and helping the citizens of Flint, MI address their water crisis (Morrison et al., 2019). He has also worked with NASA's Division of Space Biosciences to develop collaborations among life scientists. His work with a DOD contractor led to the development of a roadmap for the deployment of predictive maintenance across the Aegis destroyer fleet.

The 10 Skills of Strategic Doing

While the science of Strategic Doing is firmly based in complex adaptive systems theory, the doing is pragmatic and simple. The process is grounded in 10 skills that have been developed over years of practical application.

The Skills

1. Create and maintain a safe space for deep, focused conversation.
2. Frame the conversation with the right question.
3. Identify assets, including hidden ones.
4. Link and leverage assets to identify new opportunities.
5. Look for the "Big Easy."
6. Convert your ideas to outcomes with measurable characteristics.
7. Start slowly to go fast—but start.
8. Draft short-term action plans that include everyone.
9. Set 30/30 meetings to review, learn, and adjust.
10. Nudge, connect, and promote to reinforce new habits.

These are proven, simple steps that people from all around the community or organization can do. These are deeply embedded in the complex adaptive systems approach. Strategic Doing guides are important in the early stages of this work, but as people learn and practice these skills, the capacity of the group to address complex challenges improves.

Strategic Doing is a powerful, proven process that policy creators and writers can think about and use to make their own work much more effective.

Some Process Enneagram and Partner-Centered Leadership Stories

The City of Niagara Falls, New York has lost 50% of its population and businesses over the last 50 years. While as many as 10 million tourists a year come to see Niagara Falls during the warm summer months, it is not a source of year-round sustainable financial support. Over half of the citizens are on public assistance or retired, so there is little financial resilience or basis for sustained growth.

In 2000, the first female mayor was elected with hopes for revitalizing the City. She asked Richard Knowles to work with her and her Leadership Team to help think about the possibilities and make the improvements that were needed. The Mayor, City Manag-

er, and 18-member Leadership Team met with Knowles one evening for two hours and developed their Process Enneagram map focused on the question "how can we build the best Leadership Team possible for our City?" (Knowles, 2002, p. 78). The map they created was posted in their meeting room and briefly reviewed by the City Manager and Team at the start of their weekly meetings. Teamwork and interdependence were developed, and new ideas and possibilities were discovered and acted upon. At the end of the Mayor's four-year term the Team had eliminated $16,000,000 from a $62,000,000 budget and was able to avoid raising taxes on the citizens and businesses for three of their four years. During this time, services improved.

In another story in 2002, Knowles was invited to help a very large sugar mill in Australia reduce the number of people getting hurt during production operations. There were about 350 men producing 65 railroad cars a day of raw sugar. Each year about 35 men suffered an injury and every 12-18 months one of them was killed in an accident. Knowles helped the mill leaders develop a Process Enneagram Map addressing the question "what can safety be like in this mill?" (Knowles, 2002, p. 74). Over the next three weeks, Knowles and the mill managers went into the mill, talking together with the mill workers about safety challenges and asking how they could help reduce injuries. Everyone learned new things as they shared their experiences and perspectives. They, all together, concluded that they could work a lot more safely, and the mill did not have to hurt or kill anyone. Within three weeks, the injury rate dropped to zero and remained there for nine months, after which Knowles lost track of their progress.

In a third story, from 1993 to 1995 Knowles helped lead a community-wide effort in the Kanawha Valley near Charleston, WV in the sharing of worst-case scenarios by 13 chemical plants from eight different chemical companies with a community of 300,000 people. The use of the Process Enneagram enabled all planners to stay focused and on-track during this two-year effort. Under the U.S. Clean Air Act, any company handling a volatile, toxic material above a certain number of pounds had to share the impact of a chemical release on the community. Collaborations were built among industry people, first responders, hospitals, environmental groups (local and national), school groups, and the media. As a result of this effort, the 13 chemical plants told the community of 300,000 people about 29 scary scenarios, and trust went up.

The sharing culminated in a large conference to introduce the methodologies, an exhibit hall in which each plant manager and staff shared their particular release information and a second day of exhibits in the local, three-floor, city-block-wide shopping mall, where over 5,000 people interacted with the plant managers and their staff. The level of community-wide interaction was extraordinary. Anyone could talk directly with plant workers and ask any questions they had (Knowles, 2002, p. 51).

In all three examples, the process and pattern of interactions looked at the groups' questions from nine different perspectives.

1. Who are we?
2. What do we want to accomplish?
3. What are the issues and ambiguities blocking us?
4. What do we want our working relationships to be?
5. What specific things do we need to be doing?
6. How are we going to create and share information?
7. How are we going to learn and explore new potential and possibilities?
8. How should we be organized to do the work and how do we engage the larger community?
9. How are we changing and what new things are coming up that we need to consider?

These are proven simple steps that anyone in the community or organization can use. They are deeply embedded in complex adaptive systems theory, just like the Strategic Doing steps are.

Underlying Complexity-Based Themes

Both approaches to helping communities and organizations address and solve complex problems and have great value for things like these.

1. Communities and organizations are adaptive, complex, self-organizing networks of people. They behave as if they are a living system.
2. In gathering a diverse group of people together to engage in dialogue about an issue that is very important to them, the dialogue needs to address a well-recognized, complex problem that is known to everyone and needs to be solved.
3. The dialogue needs to be focused and use a disciplined process so that things do not degenerate into scattered conversations about a variety of different problems, lose energy, and dissipate.
4. The dialogue needs to be led by a skilled guide who knows the processes and is sufficiently experienced to keep the conversation focused on the underlying process.
5. The leaders keep simple rules in mind constantly as they guide the dialogue:
    a. Share all information, including feedback, and be sure that people understand it.
    b. Work respectfully to build trust and interdependence.
    c. Help people see the importance of their work for the success of the whole effort, thus finding meaning in their work. This releases energy, creativity, and commitment.

6. The groups must co-create their ground rules for how they are going to work together. For example:
    a. Everyone treats each other with respect.
    b. There are no personal attacks.
    c. The space is safe for anyone to speak up with new ideas, thoughts, or questions.
    d. One person speaks at a time.
    e. Questions for understanding are welcome.
    f. People must be open and honest with each other.
    g. People apologize for their mistakes.
    h. Everyone learns from each other.
    i. The work is focused on a real problem.
    j. The people learn by doing; just talking is not okay.
    k. The people self-reflect on what is happening and changing and make adjustments in their work as they go along.
    l. All information is shared and discussed as they go.
    m. The search for meaning is relentless.
7. The open, free flow of information and continuous feedback are critical.
8. Change happens one conversation at a time; it is important to keep information flows open and visible to everyone so that conversations can continue to build on each other.
9. Everyone in the process is learning from each other all the time.

Areas of Application for These Two Processes

Both Strategic Doing and the Process Enneagram with Partner-Centered Leadership can be used in virtually any complex situation to help people. Both Knowles (2002, 2020) and Morrison (2019) share many stories in their books about a variety of situations where these complexity approaches have successfully helped communities and organizations solve complex problems. However, each approach has strengths that policy writers can keep in mind as they write their programs and visualize their implementation (see Table 1).

Conclusion

Communities and organizations around the world are faced with difficult, complex problems. Most of these complex problems can be solved by the people in these communities and organizations using complexity-based systems and processes. While the sciences of complex adaptive systems and chaos are difficult, both Strategic Doing and the Process Enneagram with Partner-Centered Leadership bring simple, yet elegant tools that

can be used by any community or organization to help them effectively solve their complex problem

Both approaches are proven over decades of use in a wide variety of situations and in many countries and cultures. Trained facilitators are available and can step into most situations to help the people.

"What does our community or organization want to have happen in order to overcome the complex problems we are facing?"

"Who cares?"

We care and offer these tools and approaches to help.

Table 1. *The Two Processes*

Strategic Doing	Process Enneagram
Broad, diverse community group	Traditionally organized group (business, not-for-profit, NGO)
People come from many jobs to do this.	Most of the people are in the organization.
The timeline can be weeks or months.	The timeline is business-driven and shorter.
A recognized, steering group or sponsor is needed.	Management leads to process.
Assets are identified by group and often offered at little or no cost to the effort.	Assets are usually within the organization and allocated by management.
This addresses a community-wide complex problem.	This addresses an organizational complex problem.

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Evaluating Recommender Systems Effect on Content Diversity: An Agent-Based Framework

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Abstract

Digital markets depend on recommender systems that facilitate interactions among suppliers, distributors, and consumers, ultimately increasing sales volume and allegedly increasing user utility. Beyond this operational cornerstone, recommender systems also have a passive role in how these markets organize and behave (e.g., funneling consumers into few suppliers or promoting obscure products and services that can better satisfy consumer needs). The potential effect of recommendations appears to be larger on cultural or entertainment and media industries, where a product's uncertainty is usually high. As such, cultural diversity and market concentration on content platforms (e.g., YouTube, Spotify) are susceptible to the effect of recommendation system algorithms. The study of diversity has been a focal topic for individual recommendation optimizations, but little attention has been given to aggregated measures of diversity. Previous work on this area states that collaborative-based recommender systems have an impact on sales diversity. I expand on this, presenting an agent-based model to test the impacts of recommender systems on cultural markets. The model offers a framework to estimate the effects of state-of-the-art content-based and collaborative filtering algorithms on diversity. Early results confirm previous work. Next steps include the use of machine learning algorithms, social influence, and adaptive behavior of users. Current and future work will provide useful insights for marketing modeling, content platform policy, and the use of recommenders in market design.

Keywords: recommender systems, market diversity, agent-based model, information systems

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Evaluación del efecto de los sistemas de recomendación en la diversidad de contenido: Un marco basado en agentes

Resumen

Los mercados digitales dependen de sistemas de recomendación que faciliten la interacción entre proveedores, distribuidores y consumidores; aumentando en última instancia el volumen de ventas y supuestamente aumentando la utilidad del usuario. Más allá de esta piedra angular operativa, los sistemas de recomendación también tienen un papel pasivo sobre cómo estos mercados se organizan y se comportan (por ejemplo, canalizar a los consumidores hacia unos pocos proveedores o promover productos y servicios oscuros que puedan satisfacer mejor las necesidades de los consumidores). El efecto potencial de las recomendaciones parece ser mayor en las industrias culturales o del entretenimiento y los medios, donde la incertidumbre del producto suele ser alta. Como tal, la diversidad cultural y la concentración del mercado en las plataformas de contenido (por ejemplo, YouTube, Spotify) son susceptibles al efecto de los algoritmos de los sistemas de recomendación. El estudio de la diversidad ha sido un tema central para las optimizaciones de recomendaciones individuales, pero se ha prestado poca atención a las medidas agregadas de diversidad. El trabajo previo en esta área afirma que los sistemas de recomendación basados en la colaboración tienen un impacto en la diversidad de ventas. Amplío esto presentando un modelo basado en agentes para probar los impactos de los sistemas de recomendación en los mercados culturales. El modelo ofrece un marco para estimar los efectos de los algoritmos de filtrado colaborativo y basados en contenido de última generación sobre la diversidad. Los primeros resultados confirman trabajos anteriores. Los siguientes pasos incluyen el uso de algoritmos de aprendizaje automático, influencia social y comportamiento adaptativo de los usuarios. El trabajo actual y futuro proporcionará información útil para el modelado de marketing, la política de la plataforma de contenido y el uso de recomendaciones en el diseño de mercado.

Palabras clave: sistemas de recomendación, diversidad de mercado, modelo basado en agentes, sistemas de información

推荐系统对内容多样性产生的效果评价：一项基于agent框架

摘要

数字市场依赖能促进供应商、经销商和消费者之间互动的推荐系统；最终增加销量并据说能提高用户效用。除了这一操作性基础作用之外，推荐系统还有一个有关市场如何组织和运作的被动作用（例如将消费者细分给少数供应商或推销能更好地满足消费者需求的模糊产品和服务）。推荐系统的潜在效应似乎在文化或娱乐媒体产业更强，这些产业中产品的不确定性通常很高。照此，文化多样性和内容平台（例如YouTube和Spotify）的市场集中度容易受推荐系统算法效应的影响。关于多样性的研究一直是个人推荐优化的焦点话题，但很少有研究关注多样性的总体衡量。以往研究认为，基于协作的推荐系统对销售的多样性产生了影响。我对此进行扩展，提出一个基于*agent*模型，测试推荐系统对文化市场产生的影响。模型提供一个框架，以估计最先进的、基于内容的协同过滤算法对多样性产生的效果。初步结果证实了以往研究。下一步研究包括机器学习算法的使用、社会影响力、以及用户的适应性行为。目前和将来的研究将为营销建模、内容平台政策、以及市场设计中推荐的使用提供有用见解。

关键词：推荐系统，市场多样性，基于agent模型，信息系统

Introduction

Cisco technologies forecasts that by 2022 we will be sharing 396 exabytes (i.e., million terabytes) per month (Cisco, 2019). For perspective, the famous Library of Alexandria had 64 gigabytes of manuscripts while the British Empire Library had 162 gigabytes at the end of the 18th century, before industrialization began worldwide. This means that our monthly information creation and sharing would be over 6 billion Alexandria libraries and 2.4 billion British libraries. To answer the dilemma given by this unmanageable corpus of data, information technologies have been developed as solutions that also change how we organize at the social, economic, and political levels (Graham & Dutton, 2019). Even if we would attempt to find information without them, we would not be effective at searching or using it to improve our decision-making (Gross, 1964; Rogers et al., 2013; Toffler, 1984), a condition that makes us increasingly dependent on these technologies.

Information filtering (IF) serves a solution for the organization of relevant information (Hanani et al., 2001). Malone et al. (1987), pioneers in the study of the information-sharing dilemma, defined many aspects of Ifs, including the main two types of filters: cognitive and sociological. Since their seminal study, these two categories are usually related to content-based and collaborative filtering (Adomavicius & Tuzhilin, 2005; Falk, 2019; Hanani et al., 2001) Recommender systems (RS) are an applied use of IF with the objective to increase product sales or adoptions (Aggarwal, 2016). To accomplish its goal, the development of RS has found its roots among many disciplines and approaches. Fundamentally, a recommender design puts focus on different algorithms to predict or estimate the items that would get the best ratings from the user; in other words, they offer a subset of items that provide higher estimated utility (Adomavicius & Tuzhilin, 2005; Aggarwal, 2016; Falk, 2019). There is a vast literature around the development and application of algorithms and techniques used in RS, most involving the problem of rating estimation and ranking (Adomavicius & Tuzhilin, 2005; Aggarwal, 2016; Hanani et al., 2001). Although much effort has been put into improving their performance, research on how recommenders affect the macro-level properties and behavior of the system is scarce. An example of this is the study of diversity on systems with recommenders. At the user level, diversity in recommendations has been widely studied (Adomavicius & Tuzhilin, 2005; Behera et al., 2019; Churchill, 2018; Kunaver & Pozlr, 2017). As Kunaver and Pozlr (2017) stated, a lot of effort has been put into understanding diversity on the set of recommended items offered to the user. There are plenty of studies into and innovations regarding the optimization of the utility of users where diversity has a relevant role (Bradley and Smyth, 2001). The focus has relied on providing the most diverse array of products without dropping rating prediction. Thus, how to solve this diversity-accuracy dilemma has been a significant challenge (Zhou et al. 2010). An issue that rises from this study of diversity is the focus on recommendations themselves and not the aggregated heterogeneity of the system. These efforts focus on how diverse the recommended items are for the user (i.e., how much diversity each set of recommendations has), but they do not take into account the macro-level aggregated diversity of products in the market. It is known that some algorithms can make popular items even more salient, contributing to a winner-takes-most situation. Furthermore, the current solutions for diverse recommendations have shown that different sets across users can still lead to market level concentration (Fleder & Hosanagar, 2009). Thus, the implementation of different algorithms requires some understanding on how they affect macro-level diversity. There has been some attention on this issue, presenting the relevance of the effects that IF has over our systems' cultural or economic inequality (Fleder & Hosanagar, 2009). Access to data and experimentation with real markets recommendations is

a difficult task, but Fleder and Hosanagar (2009) presented a theoretical alternative for this evaluation. Using a Gini coefficient (Gini, 1921) as measure of system diversity, they concluded that collaborative filters increase sales inequality. Although the analytical solution and simulation provided by them opens the discussion on this topic, the challenge grows as recommender systems are today highly dependent on machine learning procedures that may be a black box for designers, managers, and users (Ricci et al., 2015).

Having in consideration that this technology inevitably contributes to shaping our organizations, culture, and markets (Graham & Dutton, 2019), this article addresses additional steps for studying their effect on product heterogeneity and how competition can be affected by the different algorithms used today. I present a theoretical approach that can be further developed into an empirically calibrated model to evaluate the impact of recommenders. The model is presented from a multi-disciplinary approach through a computational social science framework (Cioffi-Revilla, 2014), connecting social theory, statistical analysis, and the implementation of machine learning algorithms. A computational model (i.e., an agent-based model or ABM) is developed to compare a simple implementation of the two main approaches for RS: content-based and collaborative filtering. The use of an ABM enables the inclusion of relevant behaviors of the user and their interaction with the RS. Particularly, the ABM framework allows the use of industry-standard algorithms and the simulation of users that have decision rules and social interaction and that adapt to the outputs of previous interactions (i.e., modify their behavior based on results) (Epstein & Axtell, 1996; Railsback & Grimm, 2011).

Background

Analog versions of information filters have existed for centuries (Dittmar, 2011); examples like print, mass media, and advertisement are social artifacts that filter information within societies, affecting the economic and political order. Additionally, humans naturally parse relevant information during their daily interactions, shaping the formation of new habits and reducing other cultural traits (Ross et al., 2011). Beyond the mentioned literature on recommender systems, there are several considerations that are relevant in order to evaluate their effects. The diversity of systems has overall increased with the inclusion of filters, making smaller firms viable within the long tail shape of markets (Anderson, 2008). Digital products, platforms, and filters allow for digital shelf-space and other costs to be neglected. Thus, recommender systems enabled the rise of diversity on niche markets. On the other hand, the increased uncertainty of the vast libraries of products makes information-sharing an ongoing challenge.

Another critical aspect is the uncertainty present in this type of market. Understanding how individuals organize around uncertainty is key to evaluating filter's effect on products with high variance, as we can only estimate

the effect of a filter if we understand the system without it. Uncertainty presents several issues for a market, as consumers need to rely on signaling or other estimations of the product's value (i.e., their utility gains) (Hirsch, 1972). As an example, information cascades can shape the market into a path-dependency that favors a single product, regardless of its value for consumers (i.e., generating a sub-optimal social welfare) (Arthur, 1994; Bikhchandani et al., 2008). Similarly, network effects can also generate the adoption of non-optimal trades in a platform market (Evans & Schmalensee, 2016; Parker & Van Alstyne, 2018). Overall, information systems present several changes on how we organize and how it affects those products that stay competitive (Easley & Kleinberg, 2010).

When we pay attention to cultural and sales diversity, we focus on the concentration of culture and markets. In cultural industries' organization, we usually have a very uneven competition with few leaders; traditionally, it is led by a tent-pole or blockbuster business model (Elberse, 2013). Uncertainty also plays a fundamental role in this unequal competitive landscape. An example of this is Arthur De Vany's (2004) thorough analysis of how Hollywood markets organize around high volatility. One of the main reasons that cultural markets are so unpredictable is the "experience" property of their cultural goods (Nelson, 1970). This type of product, which entails the inability to be entirely assessed before consumption, has already provided evidence of its negative effect over competition and market concentration (Benz, 2007; Nelson, 1970). If competition struggles with analog information sharing, the matter of how algorithms or information filters may affect our markets becomes increasingly relevant. Their systematic effect, global reach, and propensity for feedback loops may lead to harmful results and less desired conditions of the system the technology is intended to help (O'Neil, 2016).

I present a computational model whose purpose is to evaluate the effect of basic information filters in the diversity of content purchase. To accomplish this, the model properly reproduces the behavior seen in cultural markets that rely on recommenders. This agent-based model evaluates the effect of structural elements in a market with a) a central recommender system, b) a consumer base of bounded rational users, and c) a library of experience products (i.e., unknown features, no repurchase). This captures the properties of audiovisual contents (e.g., movies, music, etc.), and therefore the theoretical model accurately represents the behavior of the streaming industry (e.g., YouTube, Netflix). The following work presents the agent-based model and early results, which leads to its verification and internal validation (Cioffi-Revilla, 2014; Railsback & Grimm, 2011). The model is designed to estimate the effect of a) filter type and b) user search capacity on the diversity of the system. As previously stated, the Gini coefficient is used as a measurement of inequality or diversity in the

model. In terms of information theory, this can considered to be Shannon's entropy (Kelleher et al., 2015), which would provide a similar measurement of aggregated diversity. Additional model parameters include the levels of uncertainty (i.e., how much information about product features is available), market size, and median sales. The results show how the use of filters affects market inequality. As this is the expected behavior of the model, particularly following Fleder and Hosanagar (2009), the results provide proof of early verification and theoretical validation. The advantage of the agent-based model is it can include relevant behaviors to be tested. Initial explorations of user search capacity show that this parameter has a mediating effect for the presence of filters, reducing its effect on higher inequality.

Model

Based on the model of sales diversity presented by Fleder and Hosanagar (2009), an agent-based model is designed following the parameters for the user marketing and product space. The assumptions and restrictions, on both their analytical and simulation approaches, can be relaxed using this agent-based framework. The simulation will be used as a theoretical tool to address hypothetical scenarios where we can assess inequality based on user behavior models and designs of information filters. For the early results, I will use this setting to determine the effect of a content-based filter has on the aggregated diversity of culture and markets. We follow a traditional model ODD protocol (Railsback & Grimm, 2011) to explain its main components and procedures.

Table 1. *Model Parameters*

Agent	Parameters	Type	Range	Initialization
Market	User population	Int	[2,40]*	[2,5,10,20]*
	Item space	Int	[0.4,8]*	[0.4,1,2,4]*
	Algorithm	Str	'N','Cg','Clb'	['None','Cg','Clb']
User	Preferences	List	[i1, ... , i100], i ∈ [0,1]	[i1, ... , i100]
	Search limit	Int	[3,30]	[3,30]
	Consumed	List	Item space	[]
Item	Features	List	[i1, ..., i100], i ∈ [0,1]	[i1, ... , i100]
	Ratings	List	[i1, ..., *i(User population)*],i∈[-1,1]	[]
	Adoptions	Int	[0,[	0

Overview

The model considers a set of users U and a library of items P that are offered in the market and available to be suggested by a recommender system. Users, items, and algorithms are represented with a set of inherent properties (e.g., preferences for each user, features for each item or product). Users are modeled as bounded rational utility maximizers. These consumer agents search for items to adopt with a limited pre-purchase or pre-experience evaluation (i.e., search behavior as defined by Nelson, 1970). The product space P represents the items from a platform's content library. Both user and item are generated by the market object, which is modeled as a third agent with access to all users, products, and the operation of the RS (i.e., no filter, content-based or collaborative). The purpose of the model at this early stage is to achieve an internal validation of the theoretical model and the simulation outputs. The experiments explore the effects of the chosen parameters over the diversity of sales. These parameters are user search capacity, recommender type, and market size.

Design

Agents

The market considers three classes of agents. The main parameters that each of these agents' use are described in Table 1. The table indicates the type and initialization values of the parameters. Along with key properties, agents also have several function and behaviors that are summarized below.

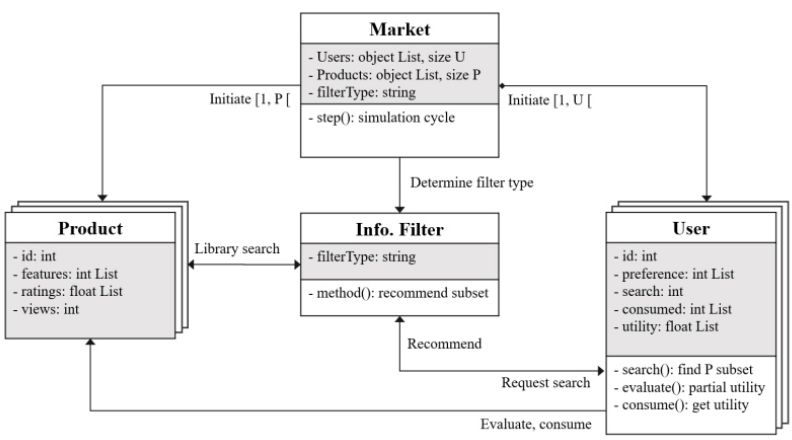

Figure 1. *Model diagram*

Market

As stated, this object represents the market environment where users interact with items and recommendation algorithms. The information filter mechanism is executed in the market agent. Thus, user agents receive recommendations from the market when a filter is active. Following this design, the market represents a single platform

where all recommendations are centralized (e.g., YouTube, Spotify, etc.). For the inclusion of the information filter both content-based and collaborative approaches have been selected.

Content-Based Algorithm

Content-based techniques provide recommendations by using the item or user properties. Known information about the item (e.g., a movie's cast members) or user (e.g., demographic data) is used to find new relevant items (Aggarwal, 2016). Among the elemental techniques used for this approach is the use of cosine similarity, which technically determines the aggregated similarity or distance between two vector values (Aggarwal, 2016; Falk, 2019). The basic algorithm includes the best-rated items by a user and a similarity matrix (created using the cosine similarity between all items). Thus, the algorithm takes the items that are most similar to those previously adopted by the user, ranks them, and offers the highest 10 items. For the purpose of the model, the market object creates the similarity matrix at the beginning of the simulation (given that the item population is fixed, and the features are known). The first 50 steps of the simulation are always executed without any recommender; after that, whenever a user activates looking for new items, the market takes their adoption records (i.e., items already acquired) and returns suggested items.

Neighborhood-Based (User) Collaborative Algorithm

The other family of recommenders known as collaborative filtering does not involve item or user information; rather, it takes data from previous adoptions or purchases. From the bare adoption (i.e., unary data) to different scales of ratings, the collaborative approach can relate users (selecting the most similar users based on these revealed preferences) or items (taking products with similar ratings). A simple technique used for collaborative filtering is Pearson's correlation (Aggarwal, 2016), which is used to estimate the similarity among the simulation user agents. As the set of purchased items changes in every step, the similarity matrix needs to be continuously updated. This is implemented in the model by creating a new similarity matrix every 5 steps. Similar to the content-based procedure, once a user searches for items under the active recommender, the agent receives the top 10 ranked items based on their similarity.

User agent. The user agent represents individuals who access the market looking for new content to consume. The basic user model only considers previous purchases, preferences, and the behaviors of search and utility estimation. Each time the user agent is activated, it proceeds to search for a new product that has not been consumed before. The searching procedure involves a random selection of products from which the user estimates utility and selects the highest value. The evaluation of utility is based in the previously mentioned dot product. The pre-purchase evaluation is done only with a restricted percentage of the total features (default value of 10%), simulating the uncertainty given by a new product. If the user decides to

purchase the product, the agent registers this to avoid re-purchase and the new rating (i.e., user's utility) is updated on the market object. If there is an active recommender system, the user goes through the same searching method but includes only the set of products presented by the recommendation (which are offered in order of relevance according to the algorithm).

As we define the users' set as U, we then consider that each user agent has as a set of preferences Ui.

$$U = \{u_1, u_2, \dots, u_{|U|}\}, |U| = userpopulation$$

$$whereu_i = \{f_1, f_2, \dots, f_{|F|}\}|F| = 100, andeachuserpreferencef_{i1} \in [0,1]$$

Thus, for each item p_i in P with features q(p_i), there is a possible utility or rating value R for any user u_j given by:

$$R(u_j, p_i) = \vec{f}(u_j) \bullet \vec{f}(p_i) = cos\,\theta$$

Items. Last, but not least, are the item agents. So far, the model includes the products of the market as a passive agent. Thus, the item class represents the available library of products (e.g., movies in Netflix) including their key properties like item features, ratings, and number of times adopted. As all items are statistically the same (i.e., their features values are generated by a Gaussian distribution), any systematic difference among products would only reflect user behavior and recommendations.

A simulation execution. A general simulation run would go through the following steps. First, it would initialize the market object with all users and product properties and the set-up of the content-based filter. Once initialization is done, the simulation begins a series of 100 steps or cycles. Each cycle, user agents are randomly activated (i.e., 50% probability of acting) and begin a limited search. If an information filter is active, users search over the product set given by the recommender. Otherwise, users get a random sample of products, which they can evaluate. As agents' properties are represented as vectors, users can estimate their utility using a dot product between product features and their personal preferences. The preference and feature sets are set to a size of 100 each. The result of the dot product reflects the similarity between user preferences and the product, which is treated as their utility and registered as the rating given to the product (if it was adopted by the agent). After all steps are over, the Gini coefficient of the total product purchases is evaluated.

Details

A detailed description of the model agents and their parameters is available on the online resources. Experiments were executed 100 times for each value level on these parameters. The model was developed

and simulated using Python 3.7.4 with Spyder 3.3.6 in 64-bit processors with Windows 10. Simulations for early results and verification were executed for the following scenarios.

Experiments

For the mentioned experimentation, simulations were separated by the main parameters. The value levels that determined the initial exploration of scenarios would consider a) the user search limit, which has two levels defined as the amount of items that the user can evaluate before purchase—these would be three items for low capacity and 30 items for high capacity—b) recommender type, which considers three levels—content-based (cosine similarity), collaborative (Pearson's), or no recommender used)—and c) market size, which considers five sets of different proportional populations of users and products.

For the default scenario, there are no active recommenders in the simulation. Users will search for possible products without information filters to expand their search. The results of these simulations are the expected outputs of the model when there are no external tools to assist consumer search. This does not model the effect of recommendations in a typical market, where other mechanisms can assist the search (e.g., word of mouth, media, rankings). Thus, we are not modeling the target system's behavior, only a benchmark to compare the impact of using basic recommender approaches. After this, to compare with against the default scenario, the simulation experiments were run using the two types of recommender systems.

Gini Coefficient

To evaluate the different distribution of adoptions, we use a Gini coefficient after all simulations are completed. The coefficient is calculated over item purchases or adoptions.

Results

Early results show a clear impact of both types of recommenders over the diversity of product sales. This implies that the use of RS results in a more unequal market, all else being equal. Under the limited model of the experiments, results provide a benchmark comparison. On average, a simulated market with content-based filtering would be expected to have a Gini coefficient of 0.336. On the other hand, a search without any recommender produces an average Gini coefficient of 0.186, with ranges between 0.169 and 0.198. Figure 2 shows the values of the output of these values for the different recommenders. The figure shows the range of Gini values, indicating how similar the effects of both RS are under this initial exploration. Based on the properties of the recommender algorithms, the content-based approach reveals a larger impact over the distribution of sales. It is important to consider that these results are based on a fixed period of 100 simulation steps. Longer runs could lead to significant differences between the approaches, especially if we consider that collaborative filtering continuously changes the recommendations.

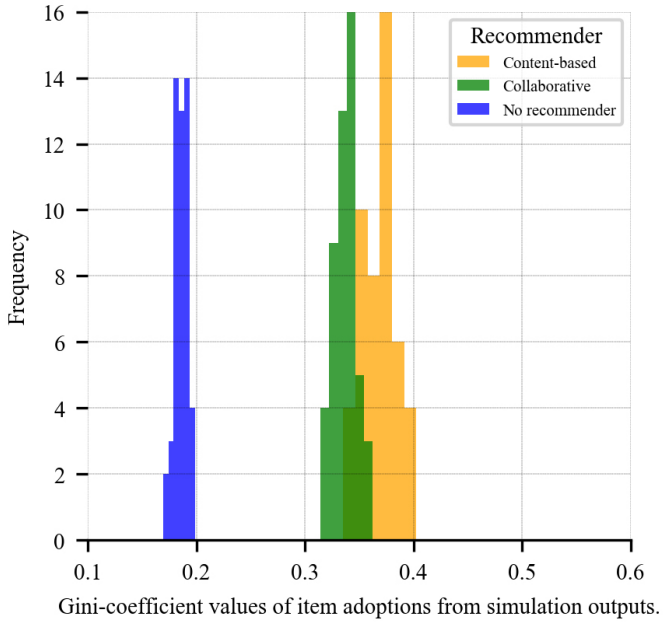

Figure 2. *Comparison of Gini Coefficient Values of Simulation Results*

Table 2. *OLS Results for the Gini Coefficients of the Simulation Outputs*

Parameter	(1)	(2)	(3)	(4)	(5)	(6)	(7)
No algorithm	0.219*						0.139*
Content-based		0.407*					0.264*
Collaborative			0.36*				0.251*
Search limit=3				0.305*			-0.038*
Views (median)					0.001*		-0.001*
User population						4.1*	2.11*

Along with the clear effect of the content-based filter and search capacity, an OLS linear regression model was developed to describe the relevance of each parameter on the resulting Gini coefficients. Table 2 presents the coefficient results for several simple regressions models using the following predictors of (1) no algorithm, (2) content-based (i.e., cosine similarity of item features), (3) neighborhood-based collaborative (i.e., Pearson's correlation of user ratings), (4) user agent search limit of three, (5) median number of item views or adoptions, (6) population size of user agents, (7) and a multiple regression with all predictors. Results indicate that content-based filtering has

the largest effect followed closely by the collaborative filtering. It is important to assess that when all predictors used are considered together, the search capacity presents a lower effect on the Gini coefficient.

Conclusion and Discussion

Considering the issue of how recommender systems affect aggregated diversity in content markets, an object-oriented model has been presented to relax the assumptions of previous work (Fleder & Hosanagar, 2009) and allow for future research on a) state-of-the-art algorithms, b) user adaptive behavior, and c) calibration at an empirical level. The purpose of this model is to estimate the effects of different filter types over the aggregated system equality. The results show that the use of recommenders affects market diversity, implying its relevance in competition and inequality. A significant effect of cognitive and collaborative filters over the Gini coefficient was the expected outcome of the model's behavior. Thus, results provide verification and theoretical validation. Additionally, initial explorations of user search capacity show that this parameter has a mediating effect for the presence of recommenders and should be explored thoroughly.

Future work considers many extensions on the current model. So far, results involve theoretical elements that can be calibrated empirically. RS do not work in isolation; including other mechanisms of influence or information spread will benefit model calibration. The inclusion of social influence is fundamental to contrast the relative effects of peer recommendations versus the RS. User agents could also be extended in their decision process, including adaptive behavior or heuristics based on consumer behavior research. Regarding the test of recommenders, the objective of this ABM framework would be to test the inclusion of hybrid and machine learning-based approaches. Finally, the current results depict the basic interaction of recommenders and users. The agent's properties were intentionally uniformly distributed and considered noise; future work should focus on other types of distributions and the design of scenarios, for example, a) having a set of products with features that would better satisfy user preferences and then evaluating recommender biases or b) setting scenarios where some products have an initial popularity advantage. For further experimentation, the optimization of the simulation environment is also under consideration. Migrating to cloud computing or using C++ for CUDA would allow for further exploration of larger market sizes.

The advantage of the developed agent-based model is set on the possible relevant behaviors to be included. This could not only help define the effect of recommenders on diversity or market competitors but also contribute to define proper algorithms that may benefit the market actors (i.e., increasing sales volume without bias and preserving optimal user utility). Returning to the dilemma of diversity-accuracy at the individual level (Zhou et al., 2010), the ABM approach can be used to test how

to maximize individual gain (i.e., user satisfaction) and minimize concentration generated by the recommender. Thus, it would be possible to find an algorithm that is not inherently biased towards cultural centralization or market concentration while providing relevant information.

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Automated Data Extraction to Evaluate Courts of Last Resort in the American States

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Abstract

Courts of last resort are becoming increasingly important in U.S. politics as the number of cases, influential decisions, and controversial issues continue to rise in the states. Unfortunately, these critical institutions are often overlooked when discussing federalism in the United States as a complex system, often due to substantial data limitations on the behavior and outcomes of these courts. In this manuscript, we situate state courts of last resort as a complex adaptive system in the broader U.S. framework. We then seek to redress the data shortcomings by introducing a comprehensive database on state courts of last resort from 1953–2010. Using advanced data

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capture techniques, we scrupulously evaluate our parsers to capture the ever-changing structures of our source documents. This database is the largest in scope and case detail to date and should further our understanding of judicial decision-making. Finally, we show trends and patterns for caseload information, case dispositions, and dissension.

Keywords: state politics, courts of last resort, data processing, complex systems, dataset

Extracción automatizada de datos para evaluar los tribunales de última instancia en los estados americanos

Resumen

Los tribunales de última instancia son cada vez más importantes en la política estadounidense a medida que el número de casos, decisiones influyentes y temas controvertidos continúan aumentando en los estados. Desafortunadamente, estas instituciones críticas a menudo se pasan por alto cuando se habla del federalismo en los Estados Unidos como un sistema complejo a menudo debido a limitaciones sustanciales de datos sobre el comportamiento y los resultados de estos tribunales. En este manuscrito, situamos a los tribunales estatales de última instancia como un sistema adaptativo complejo en el marco más amplio de Estados Unidos. Luego, buscamos corregir las deficiencias de los datos mediante la introducción de una base de datos completa sobre los tribunales estatales de última instancia de 1953 a 2010. Utilizando técnicas avanzadas de captura de datos, evaluamos escrupulosamente nuestros analizadores para capturar las estructuras en constante cambio de nuestros documentos de origen. Esta base de datos es la más grande en alcance y detalle de casos hasta la fecha y debería ampliar nuestra comprensión de la toma de decisiones judiciales. Finalmente, mostramos tendencias y patrones para la información de carga de casos, disposiciones de casos y disensiones.

Palabras clave: Política estatal, Tribunales de última instancia, Procesamiento de datos, Sistemas complejos, Conjunto de datos

应用自动化数据提取评价美国终审法院

摘要

鉴于案例数量、具有影响力的决定、以及争议性议题在美国持续攀升，终审法院在美国政治中正变得越来越重要。不幸的是，当把美国的联邦主义作为一个复杂系统进行探讨时，这些关键机构经常被忽视，这通常是因为有关这些法院的行为和结果的实质性数据存在限制。本文中，我们把州终审法院作为一个复杂适应系统，置于更广的美国框架。我们随后试图通过引入一个有关1953年至2010年间州终审法院的全面数据库，进而对数据缺陷进行纠正。通过使用先进的数据获取技术，我们严格评价了解析器，以期获取源文件不断变化的结构。该数据库在范围和细节方面目前是最广的，能促进我们对司法决策的理解。最后，我们展示了案件量信息、案件处理结果以及案件纠纷的趋势及模式。

关键词：州政治，终审法院，数据处理，复杂系统，数据集

Judicial independence is one of the most basic and controversial features of the U.S. legal system. As Alexander Hamilton (1788) explained, "The complete independence of the courts of justice is peculiarly essential in a limited Constitution." Basic precepts of fairness, impartiality, and liberty require that courts resist external political pressures and instead base their decisions on neutral principles of law and precedent (Wechsler, 1959). Yet, judicial independence also raises serious normative difficulties. As Alexander Bickel (1962) argued, "coherent, stable—and morally supportable—government is possible only on the basis of consent, and ... the secret of consent is the sense of common venture fostered by institutions that reflect and represent us and that we can call to account" (p. 20). Accordingly, policymaking by unaccountable judges may be morally unsupportable.

Despite its normative importance, the empirical understanding of judicial independence remains hotly contested. Hamilton argued that "the permanent tenure of judicial offices" would contribute to "independent spirit in the judges," but he also predicted that judges might bend to public pressure: "it would require an uncommon portion of fortitude in the judges" to resist "the major voice of the community" (Hamilton, 1788). Numerous empirical studies validate Hamilton's prediction. Despite the insulating effect of life tenure, judges tend to make decisions in

line with popular preferences and rarely stray from the dominant political coalition (Dahl, 1956; Friedman, 2009; McCloskey, 2010; McGuire & Stimson, 2004). A wide range of political, social, and institutional factors may drive the congruence between the judges' decisions and their political environments, but the mechanisms driving this association remain unclear.

Courts of last resort in the American states have become increasingly salient in contemporary political and policy debates. These courts have made numerous important decisions that have attracted praise and hostility from federal courts, national politicians, and voters. Consequently, the membership, selection mechanisms, and organization of state courts of last resort have become topics of increasing interest and controversy across the nation, as politicians, legal experts, and voters debate the proper role and design of these influential institutions.

Yet, despite the increasing importance of these questions, scholars still know relatively little about state courts, especially as they interact with other institutions and influences. Arguments regarding judicial candidates, judicial policies, judicial reforms, and the proper role of courts frequently rely on untested empirical assumptions. This debate would undoubtedly benefit from a deeper understanding of the complex relationships between state political institutions, judicial decision-making, selection mechanisms, organization, impact, attitudes, and identity within the broader social and political context. The study of these state supreme courts, and the interactions of courts, legislative, and executive branches of government at the local, state, and federal level remains non-existent outside of a handful of case studies, typically focusing on a single court case or ruling. This dearth of attention to state courts is largely hampered by limitations in data availability. Despite the importance of these institutions, scholars lack the types of data for state courts that we take for granted in the study of federal level institutions.

We seek to redress this deficiency by presenting a database of state Supreme Court cases and outcomes that we will make publicly available to the scholarly community.[1] We utilize automated textual analysis through the Python programming language and the Structured Query Language (SQL) to quickly and reliably collect data on opinions and decisions for all 52 courts of last resort. Our computer program extracted critical pieces of information from text files of state Supreme Court opinions and converted the information into quantitative data. Our data collection method produced reliable measures of state Supreme Court decision-making, facilitating a wide range of empirical analyses that are currently impossible using existing data. Re-

1 Names of courts of last resort vary across the states. We use state Supreme Court generally to identify state courts of last resort. Our database only contains cases appealed to the final appellate court within a state. In some states, these are called Supreme Courts, while in others they are called Courts of Appeal, Supreme Judicial Courts, or Courts of Criminal Appeals.

searchers will be able to explore various influences on judicial decision-making and the impact of state Supreme Court rulings through time-series–cross-sectional analysis. Our data will also inform important practical debates about judicial selection, judicial organization, inter-branch relations, federalism, and how the increasing diversity in America is reflected in the courts.

This article proceeds as follows. First, we situate state courts of last resort in a complex adaptive systems framework and discuss shortcomings of current data collection efforts on analyzing judicial behavior in this framework. Next, we describe our data collection process and then conduct reliability and validity checks by comparing our computer-generated data with existing data sets and our own hand coding of state Supreme Court dockets.

The U.S. Legal Structure as a Complex Adaptive System

The bifurcation of the U.S. legal structure into overlapping and evolving units at the state and federal level is a cornerstone of federalism in our country. This court structure was intended to allow states to remain autonomous when deciding cases based on state law, while federal courts would be focused on federal law and conflicts between the states. An unintended consequence at the time of the nation's founding was a seemingly weak judiciary at the federal level, with little in terms of formal powers. As the country grew, however, new issues, jurisdiction, and types of legal challenges did so as well. The judicial authority at the state level was equally, if not more, powerless, until the expansion of state capacity and influence following World War II, when state courts began a substantial increase in their activity.

As state courts have become increasingly salient in local, state, and even national political outcomes, scholars should adopt a complex systems approach to understanding the interactions of courts and other political units within and across states. As Ruhl et al., (2017) argued:

> legal systems exhibit what complexity scientists identify as hallmark elements of CAS. The diverse institutions e.g., legislatures, agencies, and courts); norms (e.g., due process, equality, and fairness); actors (e.g., legislators, bureaucrats, and judges); and instruments (e.g., regulations, injunctions, and taxes); are interconnected through stochastic process (e.g., trials, negotiations, and rulemakings) with feedback mechanisms (e.g., appeals to higher courts and judicial review of legislation. (p. 1377)

Figure 1 is a small example of the complexity involving actors and institutions interacting with state courts of last resort. We have classified four major areas of external actors and institutions that directly influence the inputs, outputs, and behavior of the state courts. First, the federal institutions can overturn individual case rulings if a state case is deemed to violate feder-

al law or if legislation, executive orders, or other rules are made where federal supremacy is established. In some instances, Congress will write legislation in response to a state court case; for example, the 1996 Defense of Marriage Act was a Congressional response to the Hawaii Supreme Court's ruling that allowed same-sex marriage. Most of the influence on state courts comes from the federal judiciary. In fact, Hall (2014) argued that vertical cases, those that emerge from lower-level trial courts, are more likely to be overturned in the Federal Supreme Court due to the institutional control and implementation power that the federal courts have at local- and state-level courts. Judges at the state level will be mindful of higher rates of their decisions being overturned by higher-level courts. This type of action is seen as the power of the federal judiciary challenging the institutional stability of the state court.

The mass public influences court decision-making through direct selection, retention, and replacement of state judges. Numerous studies argue that elections prompt state judges to follow popular preferences. Most of this literature focuses on the way judges reach the bench and retain their jobs. The American states vary widely in judicial selection mechanisms. Seven states elect justices through partisan elections, 15 hold nonpartisan elections, and 16 appoint members initially, then hold retention elections to remain on the court. Finally, 12 states use gubernatorial or legislative appointment, with many of these states requiring reappointment after varying term lengths or a mandatory retirement (American Judicature Society, 2013). These selection differences influence the choices judges make (Brace et al., 2001; Brace & Hall, 1990, 1993). Elected trial court judges and state Supreme Court justices are more responsive to public preferences than judges selected through appointment (Gordon, 2007; Huber & Gordon, 2004).

Other studies emphasize electoral competition; i.e., state judges may respond to public opinion only when they rationally anticipate future competition. These studies test the effects of competition in different ways. For example, judges tend to follow popular preferences when they are near the end of their terms (Caldarone et al., 2009) and when general partisan competition in the state is high (Brace & Hall, 1997; Hall, 1995). These findings suggest that judges respond to public opinion because they anticipate future competition; however, they do not capture rational expectations at the individual level. Statewide competition and the proximity of a judge's reelection contest are only indirectly related to that judge's rational expectations regarding future competition.

This rich, extensive literature offers valuable insights into policy responsiveness; yet, this groundbreaking work has been hampered by a lack of available data. For example, some studies examine judicial behavior over only a few years (e.g., Brace & Boyea, 2008; Cann & Wilhelm, 2011). Because these studies essentially employ cross-sectional rather than longitudinal data, they are unable to test whether judges change their voting behavior in re-

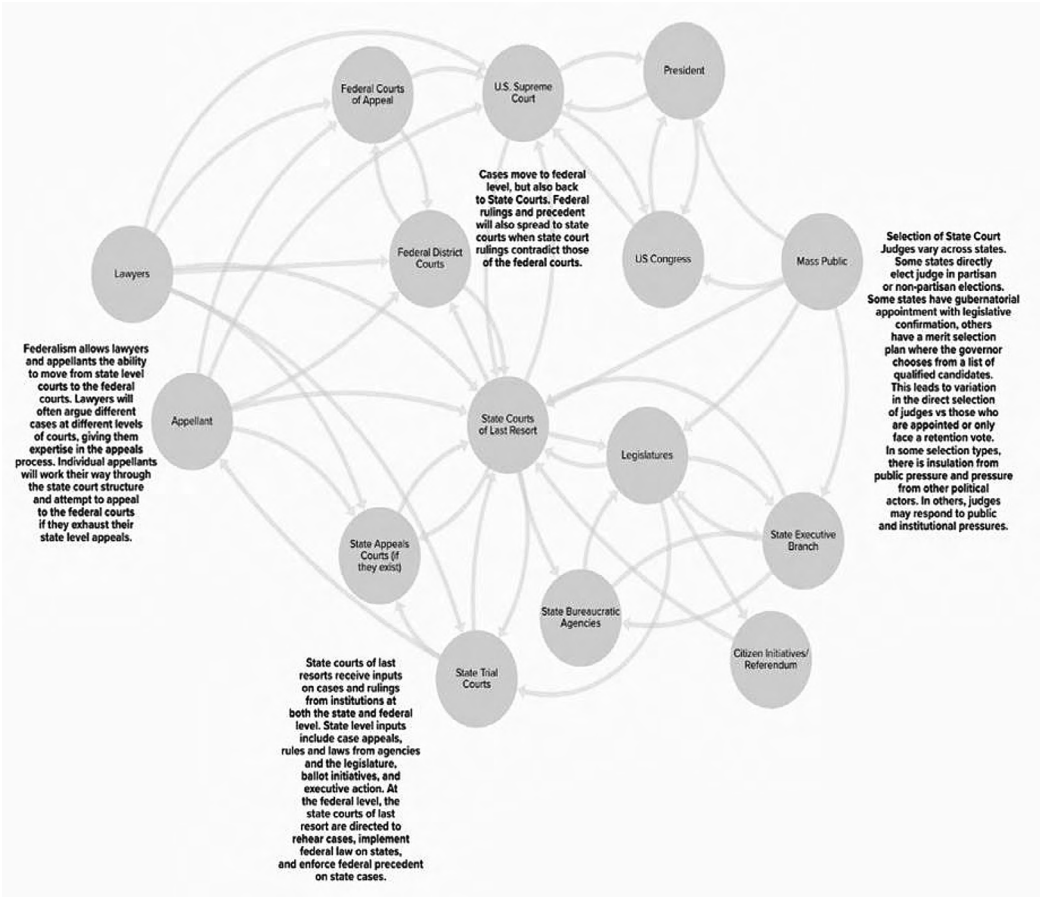

Figure 1. *Sample Complex System of state and federal legal and political institutions*

sponse to shifts in public opinion over time. Others include only a small number of states (Brace & Hall, 1997; Hall, 1987, 1995) or only states with certain selection mechanisms (Caldarone et al., 2009). Finally, many studies focus exclusively on rare case types—namely abortion (Brace et al., 1999, 2001) and capital punishment (Brace & Boyea, 2008; Brace & Hall, 1995, 1997; Canes-Wrone et al., 2014). As an example, Brace and Boyea's (2008) analysis of capital punishment decisions used only 889 out of the 15,000 cases in the State Supreme Court Data Project (SSCDP). More recently, Cann and Wilhelm (2011) used the SSCDP to examine judicial responsiveness across a wide range of issue areas. They found that only judges facing contestable elections respond to the public and then only in "highly visible"' cases, which are just 1.3% of the cases in their data (Cann & Wilhelm, 2011).

The mass public and federal institutions are only two of the external pressures that may exert influence over state courts of last resort. A more direct relationship often comes from other institutions within the state. Much like inter-branch interactions at the federal level, state institutions can be conflict-

ual or retaliate against the actions of the other institution. For example, state legislatures may pass court-curbing legislation aimed at removing powers from a state court due to ideological differences (Blackley, 2019). Likewise, state courts of last resort may invalidate or rule that state laws, administrative rules/orders, and executive actions are unconstitutional. Even governors can retaliate against state courts in budget requests and, in extreme cases, remove or fail to reappoint judges to office.

An even more crucial element of inputs in this system is cases from trial courts and intermediate appellate courts within the states. In 2017, state courts reported nearly 83.5 million cases (National Court Statistics), down 22% from 10 years prior. Of these cases, 207,321 were cases appealed to the state intermediate appellate or state court of last resort. This is not an insignificant number of cases when placed in the context of the Supreme Court of the United States. As Figure 2 shows, the number of cases decided by state courts of last resort has steadily increased from the 1950s, while the number of cases decided by the U.S. Supreme Court steadily declines. Meanwhile, roughly 20% of all cases heard by the U.S. Supreme Court were previously argued in a state court of last resort.

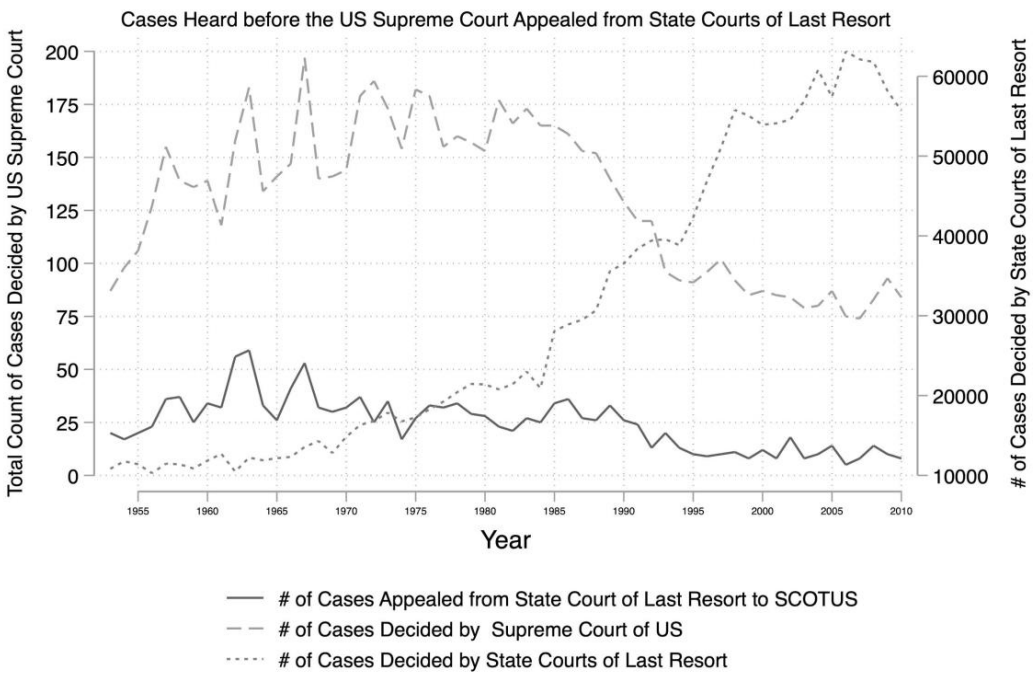

Figure 2. *Caseload Information on U.S. Supreme Court and State Courts of Last Resort Appeals*

Understanding the relationship between these external pressure, institutional structures, and judicial decision-making has important consequences for the nature of representative democracy, legal theory, and judicial

politics. By exploiting the institutional and political variation in state supreme courts, we will allow scholars the ability to directly test the role of different individual actors, selection effects, public pressure, and inter-branch relations in shaping elite policy decisions on courts. The lack of data currently available to scholars also causes potential normative implications when it comes to questions of accessibility to courts, trends in areas of increased attention by law enforcement, and general inefficiencies in court output.

Data

Data Collection Methods

Legal source documents. The source document collection is one of the critical phases of our project. Data is only useful if it is high quality, systematically collected, and free of bias. Bad data is at best inconsequential, but flawed source data could cost time in cleaning errors and ensuring the accuracy of information. Even though we have 52 state courts in the United States and millions of cases were challenged, we ensured that we used a quality data source in terms of accuracy, completeness, relevance, validity, timeliness, and consistency. One technique to collect all the case details is to directly get information from the 52 state courts. However, these courts each format their documents differently. To compile a comprehensive tool, we would need to write a state-year-specific program to extract our data. This is inefficient, increases the likelihood of non-random error, and relies on documents from states that are often not machine-readable.

To overcome these issues and maintain the metrics mentioned above, we compiled our source documents from LexisNexis Academic. This tool is a knowledge center that maintains the deep archive of federal and state court cases dating back to 1789. We sourced our data from this central repository and organized them in a hierarchical, alphabetical, and chronological order. The level of hierarchy is as follows: 1 = State, 2 = Year, 3 = Cases heard in the court. To easily traverse in the dockets and locate a case, we can make use of the unique identifiers that Lexis assigns to each individual case. Finally, we have the outcomes of the state courts of last resort in 52 states, over 58 years, and including over 1.7 million appeals. Of this figure, 584,253 were full written opinions released by the court. The remaining appeals are orders, denials of a varied nature (certiorari, dismissal, habeas corpus, etc.), legal suspensions and disbarments, and other obscure cases that sometimes originate in the states.

Judge biographical information. A major hurdle of this project is ensuring the accuracy of the judges involved in each individual case. For the U.S. Supreme Court, it is easy to identify which judges serve on which cases, as there are only nine judges and a finite number of cases. Given the national level office, each judge who has served on the U.S. Supreme Court can be identified with exact dates of service identified. State courts of last resort are not as simple, and the data is not as readily available. To begin, we needed to identify the population of judges that appear in these judicial decisions. We then cross-vali-

dated each name with state or regional reporters, state blue book biographical information, and information obtained directly from the court, state archives, or a law library.

To build the knowledge base of judges, we extracted all information that appears in a Lexis section titled "Judges." The Judges section is not consistent within a state or across states. We identified all the surnames, aliases, combinations of first and last names when available, and the first and last date the name appears in each state. After confirming with source documents from the states and other resources, we discovered 2,101 unique judges serving between 1953 and 2010. We then combined these confirmed rosters with the results of our scraper. We matched all instances of last names, combinations of names, and even misspellings, typos, and combinations of multiple names. This informed us of 5,699 different aliases used by sitting judges. We could then match these names with the text of names in different fields, as outlined below.

In Figure 3, we show how three Alabama list judges that appear in each case. As evident from this figure, some cases will report very limited information on which judges appear in each case, while others offer a very detailed description of not only the judges on the case, but also how they decide each case. This type of variation makes the background data collection on the judges a priority to ensure the highest level of accuracy with our data processing.

1953January19
262 Ala. 197; 77 So. 2d 903; 1953 Ala. LEXIS 18
Foster, Justice. All the Justices concur.

1953January19
258 Ala. 317; 62 So. 2d 918; 1953 Ala. LEXIS 234
FOSTER, Justice. LIVINGSTON, C. J., and SIMPSON and GOODWYN, JJ., concur.

1953January19
258 Ala. 303; 63 So. 2d 796; 1953 Ala. LEXIS 232
LAWSON, Justice. LIVINGSTON, C. J., and BROWN and GOODWYN, JJ., concur. FOSTER, J., concurs in the reversal of the judgment of the trial court. SIMPSON and STAKELY, JJ., adhere to the views expressed in the opinion prepared on original submission and therefore dissent.

Figure 3. *Sample Judge Section Formatting for Three Cases in the Same State, Released on the Same Day*

Courts, states, and regional reporter information. All the information of the courts, states, and regional reporter volumes has been collected from *The Bluebook: A Uniform System of Citation, Guide Version 20*. This information included the names, abbreviations, volume numbers, and dates. This information was collected to help in processing and understanding the dynamic of the case information.

Dataset Preprocessing

The raw format of our source documents were the written description of a case, actors involved, outcome, and the written opinion(s). These documents are extremely useful for legal researchers, judges, law scholars, and lawyers looking for information on a single case. However, social scientists, data scientists, and those interested in studying complex systems would need a dataset that has separated critical fields of these data for comparison, statistical analysis, and other empirical evaluations. We discuss below the pertinent information extracted for each case.

Parsing the dockets. In order to create this database, all cases in the collected dockets have been parsed and preprocessed to ensure high quality results. Two types of files have been produced after the parsing and preprocessing are complete. The first type of files is the individual majority, dissenting, and concurring opinions for each case, if these opinions were written. The second type of files is comma-separated values (CSV) files, where we stored other variables of pertinent information from the cases.

The majority, dissent, and concurring opinions. These opinions are the official ruling decided by the court and any explanation of a disagreeing position. The majority opinion is the position held by half or more of the court. These written opinions are always reported if the case has any sections labeled as "Opinion," "Dissent," or "Concur." All written opinions are extracted and stored in separate text files. We produced up to three text files for each case. Each file has only one of the case's opinions. These texts were given a unique name including the year, state abbreviation, the unique Lexis identifier, and the initial of the text type (M, D, or C). Utilizing the Lexis identifier allows us to connect the text files with the CSV spreadsheets. Other identifiers are available, as discussed below, but they are not always unique to a single case.

After creating text files for the majority, dissent, and concur texts of each case, we created 52 CSV files, one for each court. The CSV file of each court has eighteen variables describing the cases of the court. All variables were extracted from the text. We describe and discuss those eighteen variables in the following paragraphs.

The case number. This number indicates the internal case identifier used within each state. The standard manner for citing cases as advised by The Bluebook is to use the regional reporter.

The case identifiers. The citations of the case are the first variables to be extracted from the case's texts. These citations are the case identifiers in the reporters. In the documents collected from LexisNexis, each case should have between one and three citations—State Reporter citation, Regional Reporter Citation, and Lexis Citation. The Lexis citation is produced for all appealed cases if the state releases information on those cases. Prior to the widespread use of computers for storing large amounts of data, courts would only publish information pertinent to appeals that

were accompanied by a written appeal. The other cases that were dismissed, issued orders, decided without an opinion, or sent to another court were not reported on. As computing capacity increased, different case types became available. States sent their published opinions to be printed in the state and regional reporters, but other case types could be archived online. While Lexis citation is unique for each case, the Regional Reporter and the State Reporter may not be unique variables. Multiple cases may share the same reporter if they were reported on the same page and volume of the correspondent reporter. In addition, some cases do not have Regional Reporter or State Reporter if they have not been published in the correspondent reporter. Table 1 shows the definitions, structures, and examples of all these case identifiers.

Table 1. *The Case Identifiers*

Case Reporter	Definition	Structure	Example
State Reporter	The case identifier for the published cases in an official state reporter by the state	Three main elements: • The number of the volume of the reporter • The state abbreviation • The number of the first page of the case in the volume	414 Ill. 120
Regional Reporter	The case identifier for the reported cases in the regional reporter	Three main elements: • The number of the volume of the reporter • The region abbreviation • The number of the first page of the case in the volume	110 N.E. 2d 256
Lexis Citation	The case identifier in LexisNexis reporter	Four main elements: • The year of the case published date • The court abbreviation • The word 'LEXIS' • The case number	1953 Ill. LEXIS 257

Table 2. *Reporter, Lexis, and State Information and Coverage*

Reporter	Abbreviation and Volume	States Covered in the Reporter	Lexis Court Abbreviations
Atlantic Reporter	A., A.2d, A.3d	Connecticut, Delaware, Maine, Maryland, New Hampshire, New Jersey, Pennsylvania, Rhode Island, & Vermont	Conn., Del., Md., Me., N.H., N.J., Pa., R.I., VT
North Eastern Reporter	N.E., N.E.2d	Illinois, Indiana, Massachusetts, New York, & Ohio	Ill., Ind., Mass., N.Y., Ohio
North Western Reporter	N.W., N.W.2d	Iowa, Michigan, Minnesota, Nebraska, North Dakota, South Dakota, & Wisconsin	Iowa Sup., Mich., Minn., N.D., Neb., S.D., Wisc.
Pacific Reporter	P., P.2d, P.3d	Alaska, Arizona, California, Colorado, Hawaii, Idaho, Kansas, Montana, Nevada, New Mexico, Oklahoma, Oregon, Utah, Washington, & Wyoming	Alas., Ariz., Cal., Colo., Haw., Ida., Kan., Mont., N.M., Nev., Okla., Okla. Crim. App., Ore., Utah, Wash., Wyo.
South Eastern Reporter	S.E., S.E.2d	Georgia, North Carolina, South Carolina, Virginia, & West Virginia	Ga., N.C., S.C., Va., W. Va.,
South Western Reporter	S.W., S.W.2d, S.W.3d	Arkansas, Kentucky, Missouri, Tennessee, & Texas	Ark., Ky., Mo., Tenn., Tex., Tex. Crim. App.
Southern Reporter	So., So.2d, So.3d	Alabama, Florida, Louisiana, & Mississippi	Ala., Fla., La., Miss.

We found three issues after extracting the reporter citations of the cases. The first one is that some of the citations have typing errors, including, but not limited to, extra spaces between the elements of the reporter, wrong capitalization, or missing letters. The second issue is that there is no specific order for which citations come first. The third issue is that there is no specific punctuation used as a separator between the reporters. To overcome these issues and extract the reporters, we utilized the regular expressions (regex) that can identify all the cases reporters even if they have some typing errors. After that, we reconstructed those reporters in the correct formats.

The court name. One of the main variables to be extracted from the case text is the court where the case was decided. However, the case text often does not include the name of the court due to typographical errors. Consequently, we used the court abbreviation in the Lexis Citation of the case. As you can see in Table 2, each court has a unique court abbreviation. Therefore, we used the court abbreviation to link the cases with their courts. For example, in order to get the court name for the case with Lexis number (1953 Ala. LEXIS 268), we extracted the court abbreviation (Ala.). Based on Table 2, this abbreviation (Ala.) belongs to The Supreme Court Of Alabama.

The case date. Like most of the other variables, we could not find a standard format for the date of each case. There are eight different formats and some cases do not report a date. Therefore, our tool has eight different regexes to capture and extract the case date, if there is any. If the case does not have a date, the tool creates the date as the beginning of its published year based on the year in its Lexis reporter. Some cases have more than one date—the submission date and the decided date. The submission date is the date when the case was submitted to the court. On the other hand, the decided date refers to the case's decision and publishing date. To distinguish between those dates, the decided date usually is followed by one of four words—decided, released, filed, or delivered. For those cases with the couple of dates, our tool extracts the decided date that refers to the case's decision and publishing date.

Majority, dissenting, and concurring opinion writers. These writers are the judges who write the opinion(s) of the case. The majority writer is the person, persons, or court (per curium) who wrote the rationale behind the court's ruling in a case. In the source data, there are labeled sections to report the majority opinion, dissent, and concur writers, if the case has any. Those sections are Opinion by, Dissent by, and Concur by consecutively. Even with the labeled sections, extracting and processing the judges' names from the corresponding sections faced three challenges—judges' names were associated with stop words, the names were separated by different punctuations in each case, and the names were shared by more than one judge. In the following paragraphs, we explain these challenges and how we overcame them.

The first challenge to extracting the judges' names was that the judges' names were sometimes associated with descriptive words and phrases that need to be cleaned first. We considered those words and phrases as stop words. To find and clean those stop words and keep the names only, we used dozens of regex commands with textual processing techniques.

The second challenge was that in most cases, the judges' names were separated using a semicolon or colon, but in some other cases, a comma was used to separate the names. Using the comma as a separator was a problem as the comma was also used in other cases to separate the first and last name of the judges. To overcome this challenge, we replaced all colon separators by semico-

lons. After that, we checked to see if the judge's name has more than one comma and no semicolon, and then replaced all commas with semicolons. At the end, we split names by semicolon.

The third and most difficult hurdle was to map extracted names from the opinion writers' sections to the judges themselves. Most of the judges have multiple aliases in the source documents. What makes it worse is that we encountered more than one judge working on the same court and reported with the same alias—i.e., George Smith (1937–1955), Griffin Smith (1949–1987), William Smith (1958), and Lavenski Smith (1999–2000) all served on the Arkansas Supreme Court, with multiple instances of overlapping time. To overcome this challenge, we utilized the list of all the judges' names, their aliases, and their service times in the court, as outlined above. We added first initial or first and middle initial to distinguish between individuals with a common first initial. We also add "Sr" and "Jr" to surnames of judges who had parents who served on the court. We then matched names and aliases between the opinion writer names and judge section names. This added additional alias to our master roster file to include even more iterations of judge names. Most common in the opinion sections is using a judge's first and last name, while the judge section, where we compiled the initial list of judges, typically included a last name and first initial.

After dealing with all the challenges and issues of the judges' names, we generated a unique id, called judge code, for each judge in the data set. The generated judge codes consist of 2 parts—the court abbreviations, as shown in Table 2, of the court where the judge serves and a unique number represent the order of the judges in the court based on their service start date. These judge codes aimed to represent the judge's names in order to overcome the misleading, shared names.

The *disposition* and the *disposition description* of the case. One of the most critical components of the court's ruling is how they treat lower level decisions. Most of the cases in our dataset are appeals from lower level trial courts or appellate courts. The disposition of the case can take numerous different positions depending on where the case in the appeal process, the type of case, and the parties involved. A disposition can overturn or uphold lower-level decisions, it can be the result of an attorney disciplinary hearing, validation of ballot initiatives, ordering of a new trial, new sentencing, or granting/denying petitions. Overall, we have 50 disposition types. Each case has a section for the disposition. As there is no uniform requirement, or even recommendation for disposition reporting, we began our process by simply scraping the disposition section and removing words that are not associated with the ruling. Overall, 235 unique phrases were classified into specific disposition categories.

Other variables have been extracted from the text report of the cases as they were reported without any kind of preprocessing. Those variables are listed with their definitions in Table 3.

Table 3. *Additional Text Variables Extracted*

Variable(s)	Section Head in Source Document	Definition
case_party_1_appellant	No label. It is in the first line of the text until "v."	Appellant or appellee for each case. There is no distinction or ordering of which case appears first or second. We extracted this information from the title and created an indicator variable for appellant status.
case_party_2_appellant	No label. It is written after "v." in the first line of the text.	Same as above for the 2nd party in the case.
procedural_posture	PROCEDURAL POSTURE:	Ground of appeal to the court of last resort.
overview	OVERVIEW:	A paragraph summary of the case history and facts.
outcome	OUTCOME:	The Court's ruling on the appeal
counsel_1	COUNSEL: (first line)	Name and law firm/agency for attorney for case_party_1
counsel_2	COUNSEL: (second line)	Name and law firm/agency for attorney for case_party_2

Results

The data collection and processing methods led to the creation of a novel dataset of state Supreme Courts' cases from 1953 to 2010. To the best of our knowledge, this is the first dataset that covers this period. The dataset contains valuable data about more than 1,867,500 cases with more than 2100 judges who have worked on those cases in 52 courts. The Supreme Court of California has the largest number of cases (258,175 cases), while the Supreme Court of Alaska has the smallest (7,512 cases). The average number of cases among all courts is 35,913 cases. Figure 4 shows a map of each court's caseload geographically by groups of 10 in terms of caseload, while Figure 5 shows the total cases for each state.

Interestingly, we see changes over time in the number of cases released by state. In Figure 6, we show the annual number of cases released by the California Supreme Court. As evident in this graphic, in 1987, the court's caseload dramatically increased. This is not a function of cases increasing in a single year, but for one reason or another, California began to have the capacity to release all orders, certiorari denials, petition decisions, etc. This is a large amount of the work a court does, but these types of cases have often been overlooked in the collection of court data.

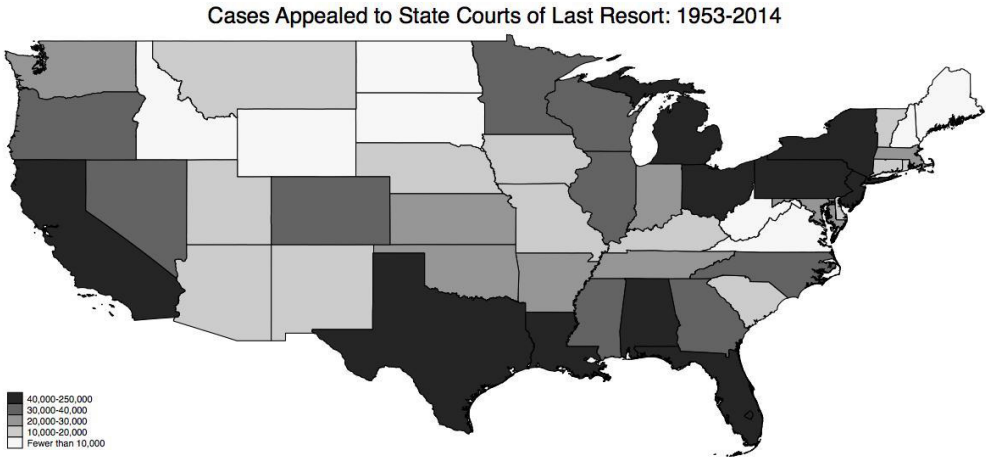

Figure 4. *Map of States with Caseloads*

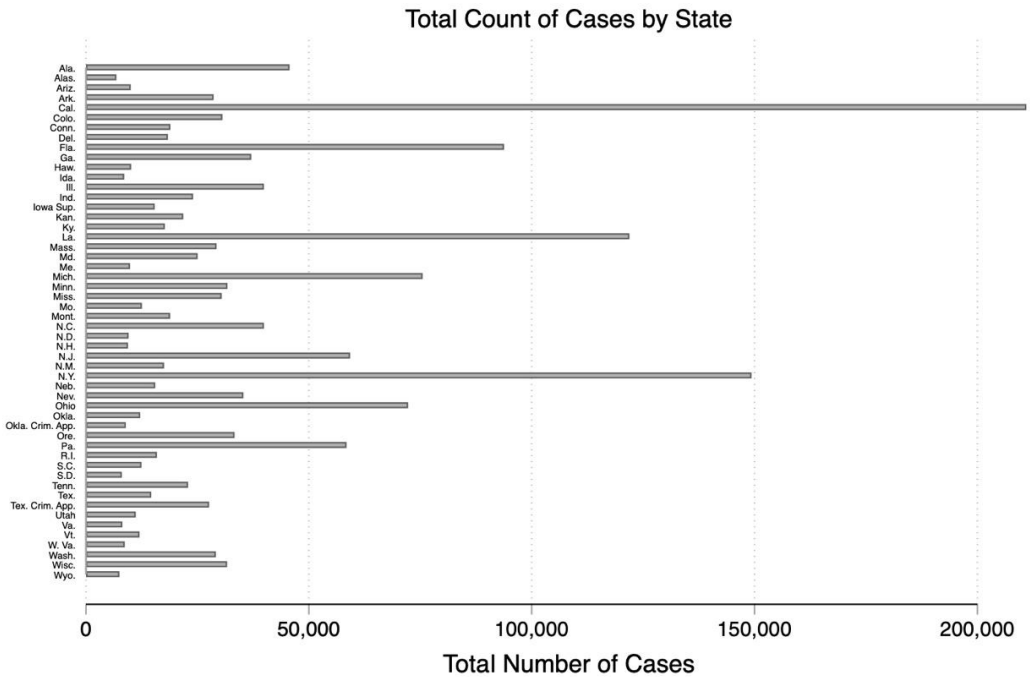

Figure 5. *State-by-State Case Breakdown*

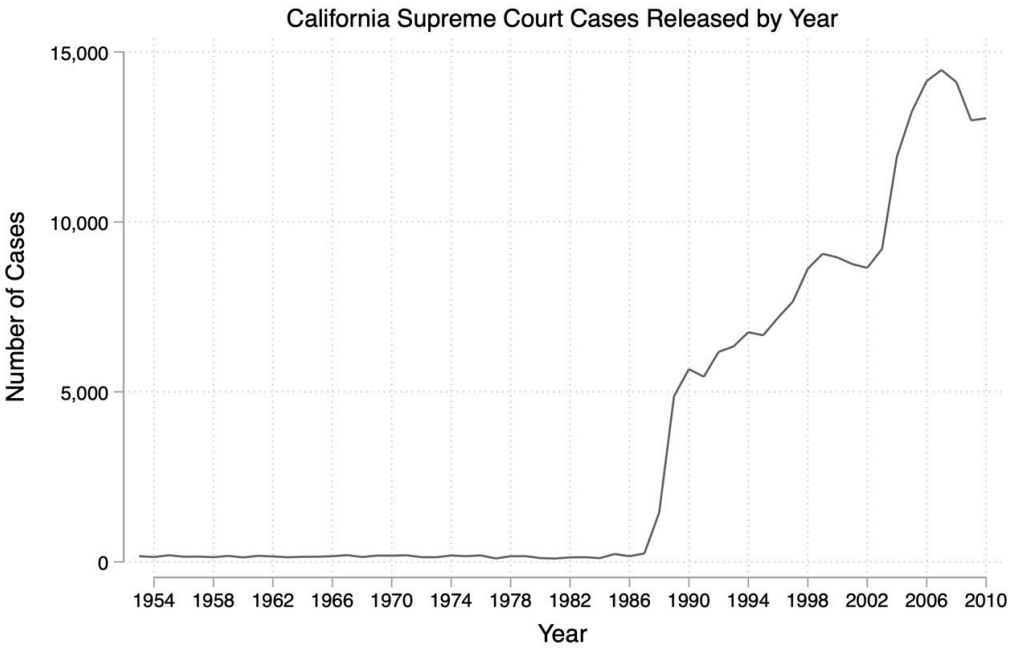

Figure 6. *Increase in California Caseload by Year*

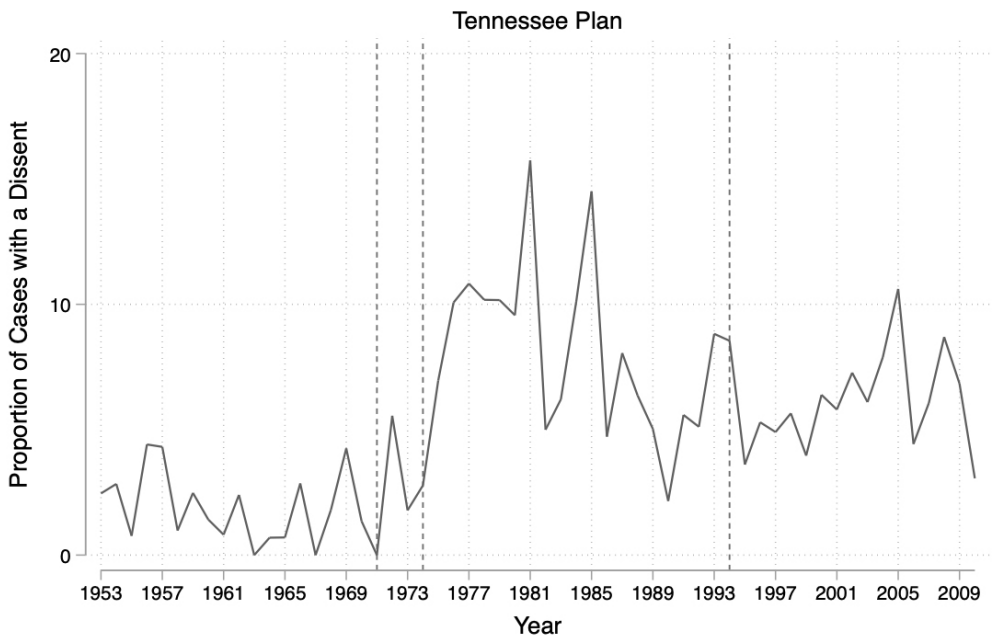

Figure 7. *Tennessee's Multiple Selection Mechanism Changes*

Beyond showing simple descriptive statistics of caseloads, Figures 7-9 show examples of what happens to a state's dissent rate when there is an institutional change forced upon the court from the outside—i.e., constitutional change, ballot initiative, or legislation that changes the institution's rules. First, we show the impact of Tennessee implementing a merit selection plan in 1970, removing Supreme Court judges from retention elections beginning in 1974, and finally reinstituting retention elections in 1994. As evident in Figure 7 there was a slow, but pronounced increase in cases with dissents immediately upon the removal of the retention requirement in the 1970s, and a small shift downward upon the adoption of the modified Tennessee Plan in 1994.

Unlike Tennessee, when Florida instituted judicial reform in the 1970s, there was little change in judge behavior. When the state moved from partisan elections to non-partisan elections in 1972 and to merit selection in 1977, the dissent rate did not see meaningful change. Most of the behavior on this court in terms of dissension occurred during the 1960s, prior to any reforms.

Not all reforms undertaken by the states were related to judicial selection. In decades prior to the 1970s, numerous Midwest states had "commissioners" who would write opinions to be voted on by the courts of last resort, taking much of the opinion writing out of the hands of the judges. In Missouri, when the state removed commissioners from writing opinions in 1973, we saw a dramatic 25% increase in cases with a dissent. It would appear as if requiring judges to write their own opinions resulted in increased disagreement within the state!

Lastly, we show how courts of last resort have been treating lower court decisions. Our collection of case dispositions allows us to closely examine these trends over time. Figure 10 plots the six most frequent disposition types. The first thing that jumps out in this graphic is the frequency of cases that the courts simply affirm the lower court's ruling. This number hit an all-time high in 1972 with nearly 7,000 affirmances. This number declined to just under 3,000 cases in 2010. Interestingly, reversals remain relatively stable over this period. Most of the changes in dispositions involve courts of last resort remanding a case, or at least a portion of a case, back to a lower court. This essentially allows appellees an additional step in the appeals process with a lower court reconsidering its ruling, often with instructions from the higher court.

The database has been reorganized and structured as a relational database to make it a searchable dataset and more usable for research related to state courts of last resort. Appendix A goes into greater detail regarding the structure, entities, and relationships between all our variables. The text of the opinions will become available in a searchable format.

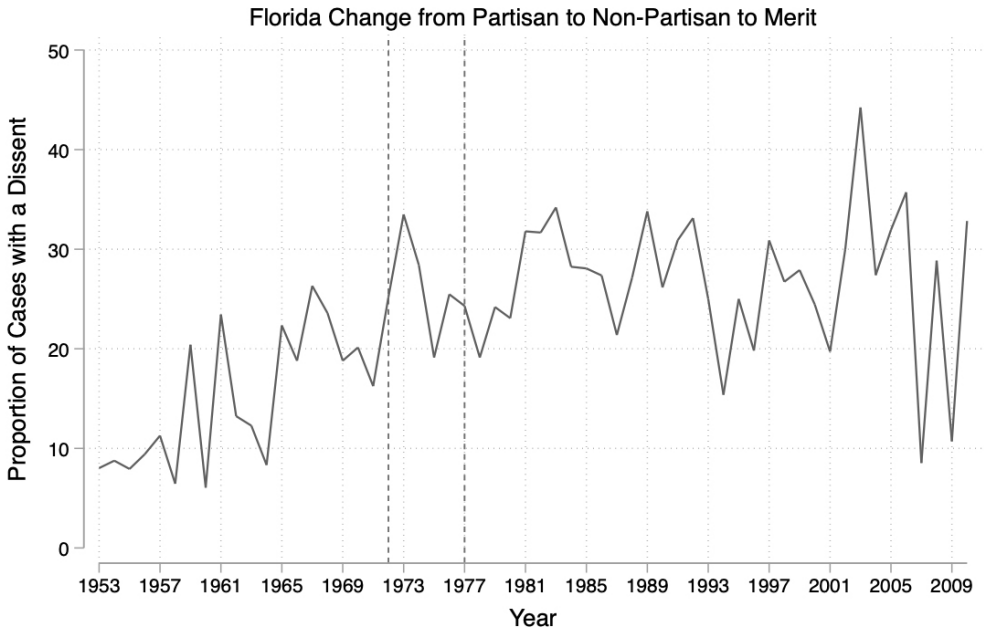

Figure 8. *Florida's Multiple Selection Mechanism Change*

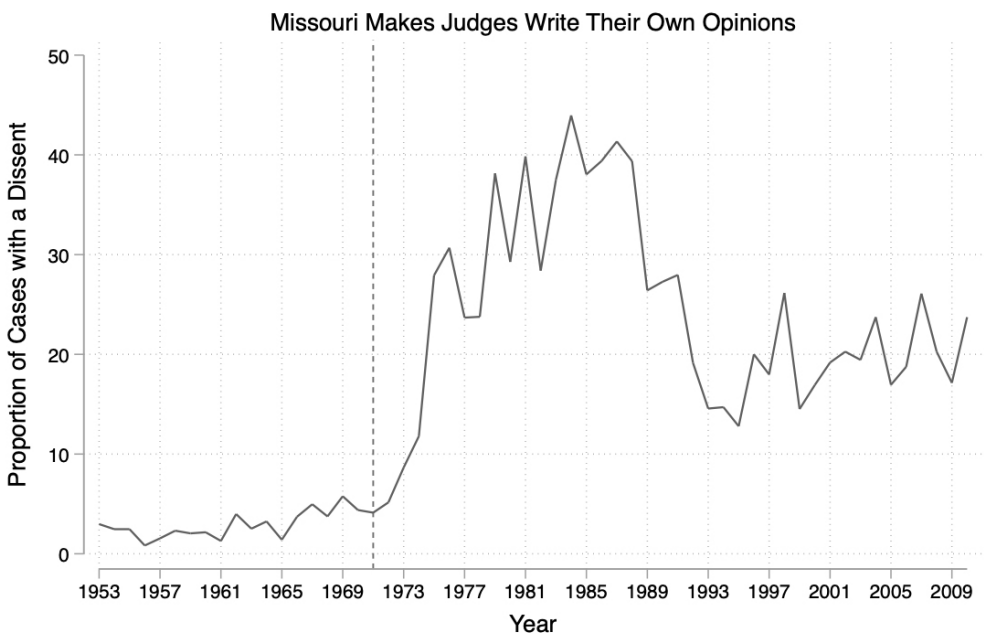

Figure 9. *Missouri's Supreme Court Removes Commissioners from Opinion Writing*

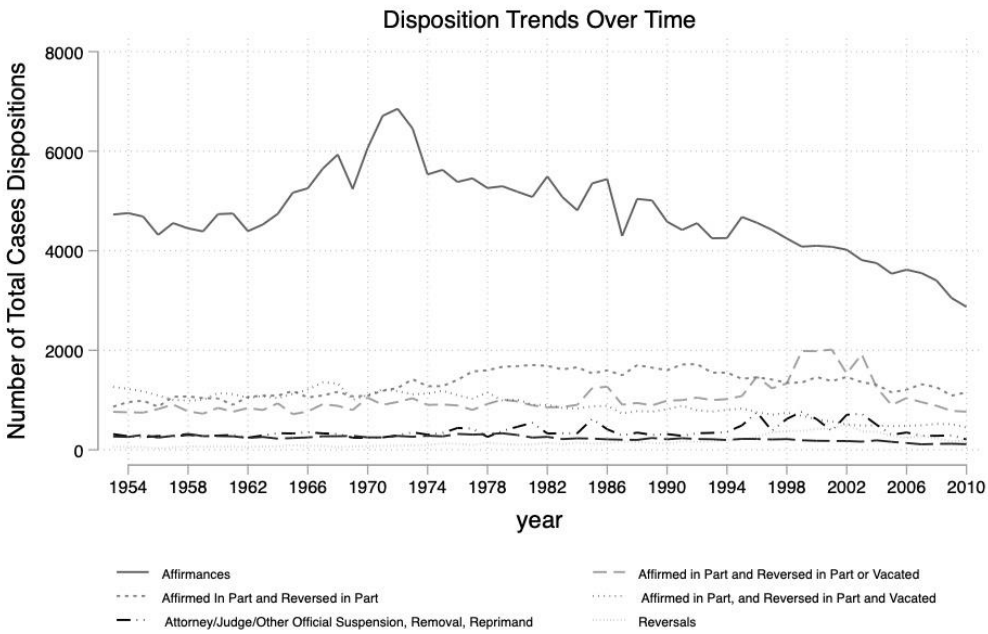

Figure 10. *Dispositions Over Time*

Conclusions and Future Directions

In this article, we situated state courts of last resort in the broader context of complex adaptive systems. As the saliency of state court cases continue to increase and the interactions of institutions become increasingly politicized, the importance of examining courts in a broader complex systems framework will allow for a more holistic analysis of federalism and institutions to compete for power. To understand these interactions, we constructed a novel database consisting of pertinent case facts and a large amount legal text data in the form of written majority, dissenting, and concurring opinions.

Future directions include utilizing our parsing tools to collect data on other judicial institutions. Federal court and state trial court data is essentially a small sample of cases with little in terms of connections to other data. As we further develop our tools, we will be able to quickly and accurately construct large datasets with similar variables and case information to make comparisons across states and to the federal level possible. This effort just scratches the surface on a plethora of other attributes we can construct from this data. We are currently expanding the data collection effort to include voting behavior for each individual judge and building citation networks of each case. Our hope is to further the understanding of judicial behavior and issues of institutional interactions over time and space.

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Appendix A

The Database Description

The dataset has been reorganized and structured as a relational database to make it a searchable dataset and more usable for the research community. Figure B-1 shows the entity-relational diagram (ERD) of the database design. In this appendix, we show the database design and the description of each table in the database.

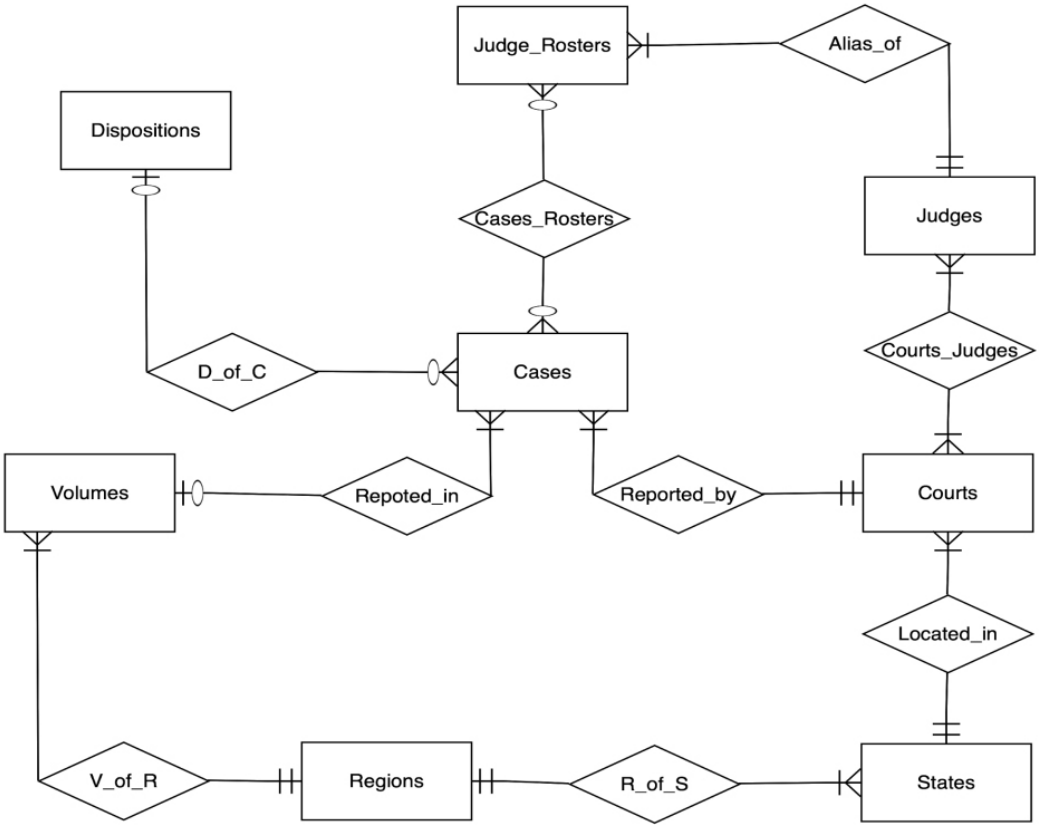

Figure B-1. *ERD of the Database Design*

Cases Table

This table is the main table in the dataset. It has all the information about the cases of all the state Supreme Courts. This table has about 1,724,264 records and 14 columns. Each record presents the data of a case and each column is a variable describing the cases.

Column name	Data type	Description
case_lexis_reporter	Text	Primary key of the table. The case id in the lexis reporter.
case_regional_reporter	Text	The case id in the regional reporter.
case_state_reporter	Text	The case id in the state reporter.
case_date	Date	The decision and publishing date of the case.
case_party_1	Text	Appellant or Appellee for each case.
case_party_2	Text	Appellant or Appellee for each case.
procedural_posture	Text	Ground of appeal to the court of last resort
overview	Text	A paragraph summary of the case history and facts
outcome	Text	The Court's ruling on the appeal
counsel_1	Text	Name and law firm/agency for attorney for case_party_1
counsel_2	Text	Name and law firm/agency for attorney for case_party_2
lexis_court_abbreviation	Text	Foreign key from the table "Courts" to connect the case to the court data of the court where the case published.
disposition_value	Number	Foreign key from the table "Dispositions" to connect the case with the disposition data of its disposition.
rr_volume_abbreviation	Text	Foreign key from the table "Regional_Reporters_Volumes" to show the regional reporter volume number in which the case has been reported. The number and abbreviation of each volume.

Regional_Reporters Table

The courts of last resort have been divided into seven groups based on U.S. geographic region. Each region has its own reporter that includes all the published cases of the region's courts. This table has the data for the seven regions. As publishing decisions online became more readily available, cases in more recent decades may include published or unpublished decisions, with unpublished decisions that hold no precedential authority in future cases.

Column name	Data type	Description
rr_abbreviation	Text	Primary key of the table. The abbreviation of the region name.
rr_name	Text	The name of the region.

Regional_Reporters_Volumes Table

This table has the data of each volume that has been published in each region.

Column name	Data type	Description
rr_volume_ abbreviation	Text	Part of the table composite primary key. The number and abbreviation of each volume.
rr_abbreviation	Text	Part of the table composite primary key. Foreign key from the table "Regional_Reporters" to connect the volume with the region. The abbreviation of the region.
rr_volume_start_date	Date	The start date of the volume.
rr_volume_end_date	Date	The end date of the volume.

States Table

This table has the states' data. Each state has one court except the state of Colorado and Texas that has two courts, one for the criminal cases and one for other types of cases. Each state is described in this table with three columns.

Column name	Data type	Description
postal_state_abbreviation	Text	Primary key of the table. The abbreviation of the State.
state_name	Text	The name of the state
fips_code	Text	The Federal Information Processing Standard state code
rr_abbreviation	Text	Foreign key from the table "Regional_Reporters" to connect the state with the region. The abbreviation of the region

Courts Table

This table has the courts' data.

Column name	Data type	Description
lexis_court_abbreviation	Text	Primary key of the table. The abbreviation of the Courts based on Lexis reporter
court_name	Text	The court name
court_type	Text	The court types. It will be helpful when different courts types and level add to the database. In this current dataset all the courts type is States Supreme Courts.
postal_state_ abbreviation	Text	Foreign key from the table "States" to connect the courts to the states. The abbreviation of the State.

Judges Table

This table has the judges' names with their ids.

Column name	Data type	Description
judge_code	Text	Primary key of the table. The judge id in the system.
judge_name	Text	The judge name

Courts_Judges Table

Since the relationship between the Judges and the Courts Tables is many-to-many, this table serves as an associative table to connect those tables. This table shows the court that each judge has worked in and the judge service start date and end date. Recall that some judges worked in more than one session at the same court. That is why the relationship is many to many.

Column name	Data type	Description
judge_code	Number	Primary key The generated judge code
lexis_court_abbreviation	Text	Part of the table composite primary key The abbreviations of the courts Foreign key from the table "Court" to connect the court with the judges who worked in that court
judge_code	Text	Part of the table composite primary key The judge code Foreign key from the table "Judge" to connect the judge with the court data and show his/her work sessions
judge_start_date	Date	The date of the first day the judge served in the court
judge_end_date	Date	The date of the last day the judge served in the court

Judge_Rosters Table

This table has the judge_id and all of their aliases used in the dataset. Recall the fact that the judges have been reported by different aliases in the cases reports.

Column name	Data type	Description
judge_alias	Text	Part of the table composite primary key. The alias used in the cases report for the judges.
judge_code	Text	Part of the table composite primary key. The code of the judge that the alias belongs to.

Cases Rosters Table

This is an associative table for the many-to-many relationship between the Cases and Judge_Rosters Tables. It shows the majority, dissent, and concurring writers (judges) of the case. The relationship is many-to-many because the case may have one or more writers and the judge may vote and write one or more cases. The relationship is between the Cases and Judge_Rosters Tables, not the Judge Table, to connect cases with judges' aliases used in the case report.

Column name	Data type	Description
case_lexis_reporter	Text	Part of the table composite primary key The *case_lexis_reporter* Foreign key from the table "cases" to connect the cases with the judges who voted on the case and their decisions on that case
judge_alias	Text	Part of the table composite primary key The judge alias and code Foreign key from the table "Judge_rosters" to connect the cases with the judges who voted on the case and their decisions on that case
judge_code	Text	
decision_type	Text	The judge's decision on the case which could be opinion writer (O) or dissent writer (D) or concurring writer (C)

Dispositions Table

This table has all the disposition values that have been created in the processing stage and their descriptions.

Column name	Data type	Description
disposition_value	Number	Primary key of the table. The code number of the disposition.
disposition_description	Text	The disposition description.

The Complexity of Climate Change and the Need For Policies of Resilience

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Abstract

The challenges presented by climate change may be the most complex issues humans have faced. It is critical to capture that complexity in ways that can be understood across disciplines. Equally daunting is the task of developing policies that can translate into actions. Scientifically, humans need to cease all use of fossil fuels as soon as possible, which could wreak havoc on global economies. This paper explores the design of policies that could move human societies towards resilient and biophysically sustainable systems. The petrochemical industry is considered as an example for change.

Keywords: complexity, policies, resilience, climate change, petrochemical industry

La complejidad del cambio climático y la necesidad de políticas de resiliencia

Resumen

Los desafíos que presenta el cambio climático pueden ser los problemas más complejos a los que se han enfrentado los seres humanos. Es fundamental capturar esa complejidad de manera que se pueda entender en todas las disciplinas. Igualmente de abrumadora es la tarea de desarrollar políticas que puedan traducirse en acciones. Científicamente, los seres humanos deben dejar de utilizar combustibles fósiles lo antes posible. Posiblemente, eso podría causar estragos en las economías globales. Este documento explora el diseño de políticas que podrían llevar a las sociedades humanas hacia sistemas resilientes y biofísicamente sostenibles. La industria petroquímica se considera un ejemplo de cambio.

Palabras clave: complejidad, políticas, resiliencia, cambio climático, industria petroquímica

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气候变化的复杂性与复原力政策之需

摘要

气候变化带来的挑战可能是人类面临的最复杂的问题。关键在于，将复杂性以跨学科的方式进行理解。同样令人担忧的任务是发展能转化为行动的政策。从科学的角度来看，人类应尽快停止使用一切化石燃料。从可行性来看，这可能会对全球经济造成破坏。本文探究了能推动人类社会向具备复原力、在生物物理上可持续的系统发展的政策设计。石油化工产业被视为一个需要变革的例子。

关键词：复杂性，政策，复原力，气候变化，石油化工产业

Introduction

There is arguably no more complex problem facing humans than climate change in all its manifestations. It affects every other subsystem on Earth and potentially our survival, as well as that of many other species.

The Anthropocene defines the period of time in which human behaviors began to affect the biosphere itself (Crutzen, 2002). Some would date the beginning of that epoch to the use of fire by human ancestors; others to the development of tools, which allowed humans to become effective hunters of meat for food; and still others to the agricultural revolution, allowing for stable villages and cities and the specialization of labor.

The most significant changes may have started with the advent of the first industrial revolution, when fossil fuels powered the first industrial machines (Encyclopedia Britannica, n.d.b): coal powered steam engines, which in turn removed water for coal mining. Coal then drove locomotives, as trains moved people and goods across continents. The internal combustion engine, fueled by gasoline, took over the transportation industry, while coal has remained critical for the generation of electricity for many years. Modern civilization, from the industrial revolution onward, has been powered primarily by fossil fuels, and that remains true today.

Some effects of burning fossil fuels (primarily coal) could not have been missed, even early on. Smoke-filled industrial cities became common, and persist in China, India, and other advancing nations. At the beginning of the industrial age, however, the Earth seemed so vast that it could absorb or dismiss any human activity. Waste and pollution were counted as "externalities" for production. No one considered themselves responsible or liable for our collective impacts.

Increasing awareness of environmental issues date back to the late 19th century. During that era, the Sierra Club was founded, Yellowstone was established as the first national park in the United States, and Gifford Pinchot became the first chief of the U.S. Forest Service (Encyclopedia Britannica, n.d.a).

Eventually, industrial effects could not be ignored. Rachel Carson's book *Silent Spring* documented the damage from synthetic pesticides and countered disinformation from the chemical industry (Carson et al., 1962). Then, on June 22, 1969, the Cuyahoga River in Cleveland, OH burst into flames. According to a report by *Time*, it marked the beginning of the environmental movement in the United States (Latson, 2015). Greenpeace was founded in 1971, and the U.S. Clean Water Act was passed in 1972.

The Club of Rome was established in 1968, and by 1972 its research study about the problems of mankind was published in *Limits to Growth* (Meadows et al., 1972). That computer simulation model, using system dynamics, was built on several major trends that were of particular concern to the Club of Rome: industrialization, population growth, malnutrition, nonrenewable resources depletion, and environment deterioration (Meadows et al., 1972) The report was immediately and soundly criticized on many fronts, in terms of its data, accuracy, and audacity to question economic growth (Passell et al., 1972). It should be noted that this approach to the study was a second choice by the Club of Rome, after the initial proposal was rejected as being too complicated for the public at-large (Christakis, 2014). Ironically, projections made in the original study have been revisited and have been found to be more accurate than expected (Hall & Day, 2009).

As a U.S. Representative, Al Gore initiated the first congressional hearing on climate change in 1981. He published the book *Earth in the Balance* in 1992, and soon after his presidential defeat in 2000, began his presentations (later a book and movie), titled *An Inconvenient Truth*. That raised a new level of public awareness about climate change in the United States (Gore, n.d.).

Air and water quality have improved in many places since the environmental movement began, due largely to government-imposed standards, but the United States remains one of the largest contributors to greenhouse gas emissions in the world.

It is doubtful that we would have the modern societies in which we live today had the concentrated energy of fossil fuels not been discovered. But those same fuels now threaten the balance of our biosphere. The effects of fossil fuels, via greenhouse gases, have taken over as the greatest environmental threat today.

Agreement about the larger effects of climate change has been building among scientists for decades (Cook et al., 2016). The first world climate conference was held in 1979, the Intergovernmental Panel on Climate Change (IPCC) was established in 1988, the

Earth Summit in Rio de Janeiro took place in 1992, the Kyoto Protocol was adopted in 1997, and the Paris Agreement was adopted by the United Nations Conference of Parties in 2015 (UNFCCC, 2019).

The World Economic Forum publishes an annual *Global Risks Report*, assessing the top 10 concerns by world leaders. From 2007 to 2010, none of those concerns were related to environmental issues. In 2011, five were environmentally related, but by 2015, it was down to two. In 2020, eight of the 10 highest ranked issues were related to the environment (WEF, 2020).

Financial and business leaders increasingly focus on both the risks and opportunities related to climate change. The insurance industry, for instance, faces increasing losses for climate-related disasters (storms, floods, fires, etc.) Flooding is increasing in coastal areas due to rising sea levels and storm surges. Fires have increased due to droughts (e.g., Australia and California). Travel and transportation industries face different kinds of losses and disruptions. Business operations must prepare for supply chain problems. Fossil fuel companies face the threat of trillions of dollars in "stranded assets," resources that are accounted as assets financially, but may never be extracted or used.

Entrepreneurs see significant potential in alternative energy investments and new technologies. Wholesale change to new energy sources will require immense investment in infrastructure around the world. Electrification of all end-use of energy (cars, machines, residential appliances, etc.) will require major investment at the consumer level.

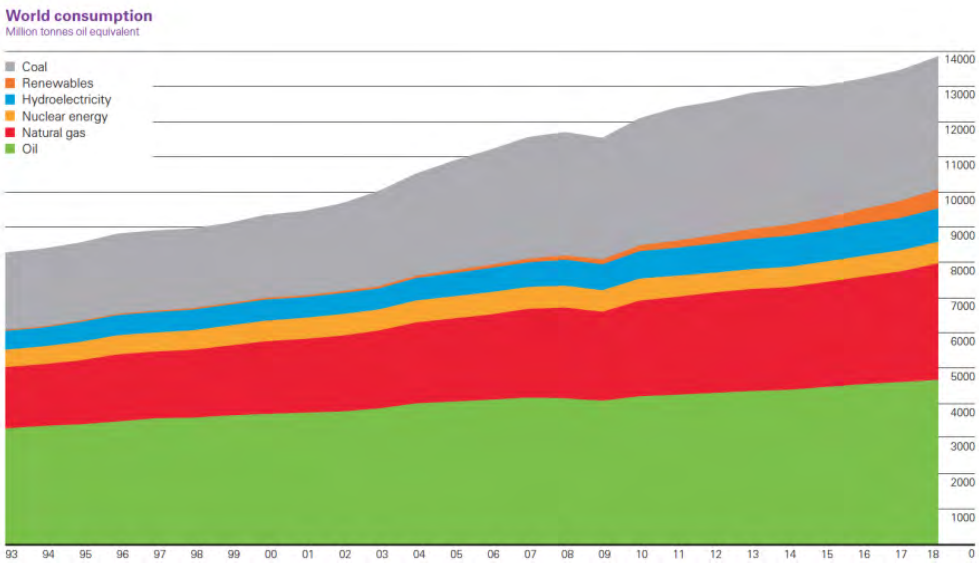
Despite the progress in science and the increase in public awareness, little progress has been made in our use of fossil fuels or the release of greenhouse gas emissions. According to a report by British Petroleum (BP), in 2018, primary energy consumption grew at a rate of 2.9%; almost double its 10-year average (BP, 2020). As a result, carbon emissions grew by 2%, the highest rate of increase in seven years. Collectively, India, China, and the United States accounted for two-thirds of the increases in energy demands (Figure 1).

There is a drastic need for change. Effectively, we need a new energy revolution, one that equals the fossil-fueled industrial revolution, but based on renewable (ultimately, solar) energy (Smil, 2017). More importantly, we do not have hundreds of years for that to evolve. This change needs to happen in years, not centuries.

Humans have never faced a more complex issue than climate change, but we did not arrive at this state due to malice or bad intentions. Progress created unintended consequences. Many, many things got better for humans, but at the cost of damage to the planet.

The Science of Climate Change

At the highest level, the thin veneer of atmosphere in which we exist is a self-organized system, sustained by energy from our sun. It took about a half-billion years for Earth's atmosphere to stabilize. After



Global energy consumption increased by 2.9% in 2018. Growth was the strongest since 2010 and almost double the 10-year average. The demand for all fuels increased but growth was particularly strong in the case of gas (168 mtoe, accounting for 43% of the global increase) and renewables (71 mtoe, 18% of the global increase). In the OECD, energy demand increased by 82 mtoe on the back of strong gas demand growth (70 mtoe). In the non-OECD, energy demand growth (308 mtoe) was more evenly distributed with gas (98 mtoe), coal (85 mtoe) and oil (47 mtoe) accounting for most of the growth.

Figure 1. *World Consumption*
Source: BP (2019, p. 10).

life first appeared, it was at least another billion years before the earliest organisms created the oxygen-rich environment that we know (Marshall, 2009). The first mass-emergence of life (the Cambrian explosion) happened less than 550 million years ago and was followed by at least five major extinctions (Kolbert, 2014). It is estimated that 99% of all species which ever existed are now extinct. The Earth has existed in many variations, with and without life, for 4.6 billion years, and could carry on, with or without humans, into the future.

Fortunately, our biosphere is extremely resilient, but it is also extremely fragile. The atmosphere is approximately 78% nitrogen and 21% oxygen. Neither of those gases retains heat. Water vapor, however, does, helping to create the "greenhouse effect" that makes our biosphere habitable for current life forms. Carbon dioxide (CO_2) also traps heat. Even though it only comprises 0.04% of our atmospheric gases, it has significant effects on global temperatures. A little bit goes a long way.

The most common models related to climate change, and to the Anthropocene in general, show changes of individual factors over time (e.g., CO_2, average temperature, gross domestic product, human population, etc.) (Steffen et al., 2015). Studies have found both correlational and causal relations; for instance, there is evidence of temperature change in relation to concentrations of CO_2 in ice cores dating back hundreds of thousands of years. Establishing predictive models of more complex systems, though, is more difficult. As a placeholder, Figure 2, below, presents a very simple depiction of just a few factors involved in climate change.

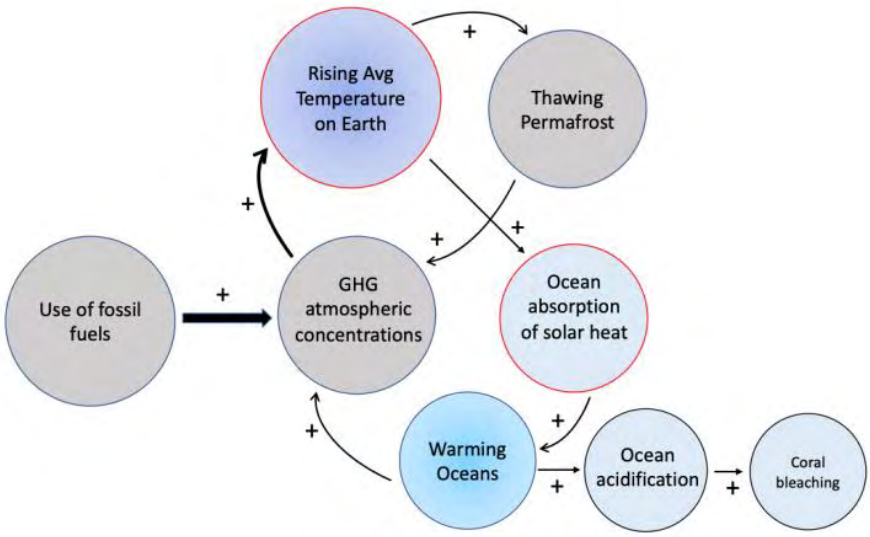


Figure 2. *Cycles of Green House Gas Effects*

The most significant lesson to be taken from Figure 2 is that, at present, there are few, if any, negative (i.e., balancing) feedback loops. If humans continue to pour greenhouse gases into the atmosphere, then global warming will continue to increase.

Models and Predictions

The lack of predictive models of climate change has allowed for a great deal of resistance and controversy. How bad will the problems become, and how quickly? Are the melting glaciers going to submerge Miami, or just cause higher tides and a little more flooding? Have the fires in Australia in 2019 and 2020 been related to climate change, or are they just normal, periodic events? Were the fires in California related to power lines, forestry or real estate mismanagement, or primarily to a dryer climate? There have been floods and droughts and storms around the world, but those happen every year —some worse than others.

For the human population at large, it is not just a question of what might be expected, but also whether anything can be done. Will people need to change their lifestyles, and if so, can they afford to do so? Will they pay more in taxes, or will they lose their jobs (like coal miners, but across many industries)? Will there be less food, or will there be true crises? Will even the most extreme changes be enough to alter climate change?

Some of the first environmental models date back to the 1950s through the work of brothers Eugene Odum and Howard T. Odum, and their development of "systems ecology" (Hall, 2021). H. T. Odum was intrigued with the energy flow in ecosystems, and used models adapted from electronic circuitry to explain environmental processes. By the 1960s, he had developed early computer models based on those same

concepts. As explained by Hall (2021), H. T. Odom:

> viewed wires as analogous to trophic (food) pathways, capacitators as analogous to storages of energy within a trophic level (i.e., biomass), resistors as energy flowing into respiration or predators and triodes or transistors as "work gates" where one energy flow influenced larger energy flows (such as energy invested by a predator into catching a prey). (p. 5)

As a general systems theorist and practitioner, H. T. Odum was interested in models that applied to many domains. He applied the same models of energy flows to cities, hurricanes, and celestial movements.

Digital computer models expanded significantly in the 1960s (Hall, 2021). The International Biological Program, modeling five basic ecosystem types, was spread across Oak Ridge National Laboratory (the principal), as well as Colorado State and Oregon State Universities. H. T. Odum expanded his work to simulate natural ecosystems, including "man and nature," at the Universities of North Carolina and Florida. Independent researchers, including Buzz Holling, focused on resource management.

Holling's (1973) work is associated with resilience, adaptive cycles, and the Panarchy model (Bunnell, 2002). He was careful to distinguish between systems such as those designed by an engineer, which had few and specific variables, in which the goal was to minimize variance, and those in which the goal was survival. The former was simpler and amenable to quantitative measurement; the latter, more complex and better understood qualitatively.

Holling was interested in real-world systems. Models were based on assumptions of equilibrium that rarely existed in the natural environment, but they might approximate a freshwater pond or lake in a relatively unchanging environment.

Holling distinguished between two types of systems behaviors. Stability is the capacity of a system to return to a state of equilibrium after a disturbance. The faster the return and the less fluctuation in the process, the more stable the system. Resilience, by contrast, is a measure of persistence. The more they can absorb change while maintaining essential relationships (e.g., between populations or state variables), the more resilience they display.

The Panarchy model was described by Gunderson and Holling (Gunderson & Holling, 2001). The original graphic, shown in Figure 3, was designed by Pille Bunnell. Bunnell (personal communication, Feb. 5, 2020), a former student of Holling, prefers an updated definition from Carpenter and Brock (2008): "Resilience is a broad, multifaceted, and loosely organized cluster of concepts, each one related to some aspect of the interplay of transformation and persistence." Bunnell further questions the specificity of concepts about resilience, including the rate that might be adequate for re-

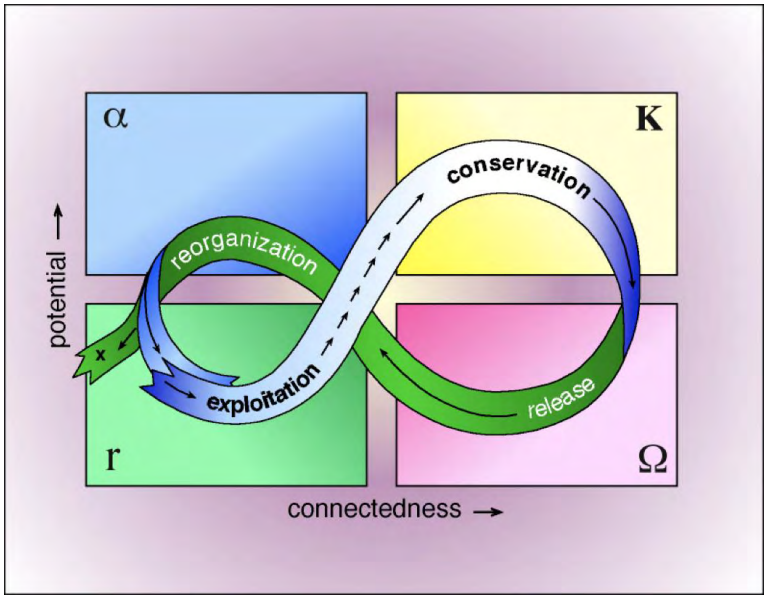


Figure 3. *Panarchy Cycle of Adaptive Change*
Source: Used with permission of Pille Bunnell.

silience (years vs. millennia), what stability would mean in dynamic systems, distinguishing a perturbation from a normal variation, and the choice of the system in question (always the somewhat subjective choice of an observer).

With respect to climate change, the Panarchy model provides a general way of describing adaptive and regenerative cycles across the biosphere. While an individual model might be useful for discussing a specific type of ecosystem or factors in a specific geographic region, a more complex picture emerges when described in terms of nested cycles interacting across something like the food web in a region of the ocean. Alternatively, the transportation system of a city or region might be described in terms of flows of people and goods, or in terms of energy—or a complex map of all relevant factors.

As noted, there are aspects of natural ecosystems that can be captured in rigorous models. The very nature of modeling, however, implies the selection of variables by a researcher, often bounded by the researcher's background and interest or professional training or (for computer models) the programming of software. For complex phenomena, Hall (2021) explained that:

> in real systems, including biological and social systems, there may be many causative agents when the human mind seems to be formed to seek a single explanation. Thus a hurricane or a population crash in nature or a stock market crash may have not one but many causes. (p. 12)

This closely mirrors a definition of complexity by Robert Rosen with respect to his "modeling relation" (Rosen

et al., 2012) A model is a formal system created by the encoding of "percepts" (perceptions) of an observer about a phenomenon in the world (the natural system). There are limited ways of "interacting with" simple systems. Complexity is as much a matter of the observer as the system in question. If there are many ways of interacting with a given system, and therefore many ways of modeling that system (many ways to describe causality), then the system is considered complex.

Lane's focus in on ecosystem-based management (EBM), involving both the human use and the ecological sustainability of specific ecosystems, like fisheries (Lane, 2021). She explains the complexity of the systems that she studies:

> Systems possess properties and behaviors that their parts do not, and ecosystem conceptualization involves whole system understanding. Lane (2018a) and Rosen (1995) have described ecosystems as chimeran systems of cooperating species that trade functions among themselves. Ecosystems are genuine self-organizing and self-referential systems and not random assemblages of species found together merely because their tolerance curves overlap. Furthermore, ecosystems are connected to other complex systems: societies and economies. (p. 4)

Lane (2021) proposes that EBM requires three levels or types of theories, for (1) description, (2) prediction, and (3) intervention, and then argues for the inclusion of qualitative analysis in ecological modeling. Her specific methodology is loop analysis. Type I loop analysis is essentially heuristic, the drawback being that models are created primarily from the intuition of the investigators. Type II loop analysis fits actual data to the models. The goal is to create an ecological skeleton of "the ecosystem's causal dynamics using the most frequent variables and links" (Lane, 2021, p. 13).

Lane (2021) associates her use of loop analysis with causality, via Aristotle's four causes. This allows her to connect her work to that of Rosen, and to Kineman's extensions of Rosen's ideas (Kineman, 2019).

Scenarios

In the absence of predictive models, researchers have proposed scenario planning. Reports from the IPCC have attempted to be both comprehensive and cautious in their estimation of future effects. In a 2018 report, the IPCC uses what they refer to as "calibrated language," assessing the likelihoods of many possible outcomes or results of global warming to be: very low, low, medium, high, or very high (Allen et al., 2018).

The key targets of the Paris Agreement are to keep "global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius" (UNFCCC, 2015, p. 3). According to the IPCC 2018 report, av-

erage global temperatures have already increased by 1 degree Celsius, due to past human activities. The greenhouse gases currently in the atmosphere will remain there for thousands of years (unless an effective means is found for removing them) and continue to cause rising temperatures. If no additional accumulation of greenhouse gases occurs (net zero), temperature increase is likely to remain at or below 1.5 degrees Celsius. That would mean an immediate halt to human production of greenhouse gases—effectively the immediate end of the use of fossil fuels. Thawing permafrost and warming oceans will release additional carbon into the atmosphere for some time.

As seen in Figure 1, immediately ceasing all use of fossil fuels would be catastrophic to the global economy and to current and rising living standards in all countries. It raises the most pressing paradox about climate change: "We must, but we cannot." That view, of course, resides within a mental framework. It assumes, for instance, that the long-term problem (potential collapse of the biosphere) is less certain than the short-term problem (potential collapse of the global economy). Or, in its most cynical form, that current decision-makers will be dead before the worst of the effects take place.

Neither the Paris Agreement nor the IPCC reports require such drastic action. Targets at present are set to achieve net-zero carbon emissions (i.e., full decarbonization) by 2050. Opinions vary as to the outcomes of varying levels of reductions over time. The primary problem, as noted already, is that progress on a global scale has yet to begin.

Figure 4 shows data and projections from the International Energy Outlook (Energy Information Administration, 2019). As noted, both our total use of energy and our use of fossil fuels are projected to increase rather than decrease (despite the somewhat positive rise in renewable energy sources).

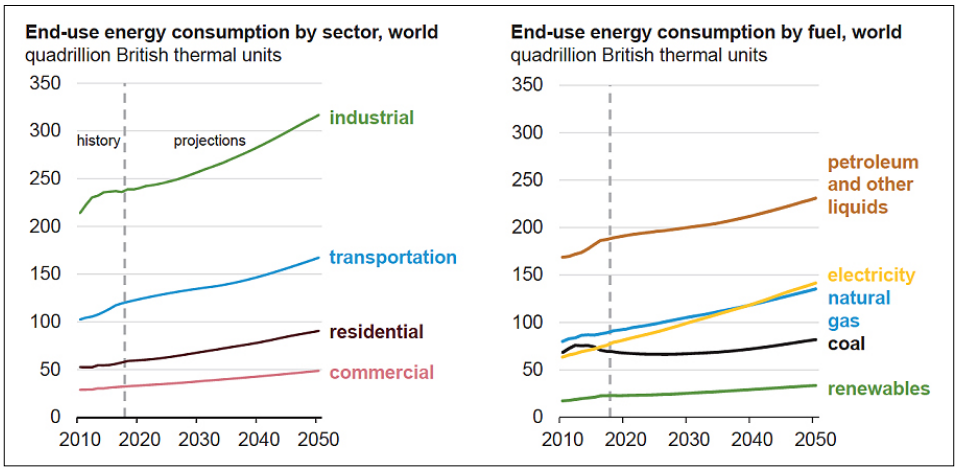


Figure 4. *International Energy Outlook*
Source: Energy Information Agency (2019, p. 29).

Policies for Complexity and Climate Change

Our current situation challenges the very concept of a policy that might be comprehensive enough to matter. Definitions for the term "policy" offer a few interesting ideas:

- "prudence or wisdom in the management of affairs"
- "a definite course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions"
- "a high-level overall plan embracing the general goals and acceptable procedures especially of a governmental body" (Merriam-Webster, 2016).

In a more formal sense, a policy might be understood as governance system or a cybernetic system regulated by reinforcing and balancing feedback mechanisms. Against that backdrop, how might we consciously plan to create the magnitude of change, which has only occurred through evolving, self-organized processes in the past?

In terms of potential policies for action, the Center for Climate and Energy Solutions has proposed three scenarios, or alternative pathways, for decarbonizing the U.S. economy (Center for Climate and Energy Solutions, n.d.). The first, "a competitive climate," relies on strong federal action in the form of carbon pricing, emissions standards and investment in research. The second, "climate federalism," looks to states to take initiative, with later coordination to unify standards and actions. The third, "low-carbon lifestyles," essentially leaves change to grassroots and market forces. Interestingly, their projections from the scenarios show virtually no difference in outcomes by 2050. All are shown as demonstrating nearly equal end states (the reduction of U.S. green house gas emissions 80% below 2005 levels by 2050).

A significant limitation to the proposal is that the scenarios are built only for the United States. At a global scale, there is no governing authority. The best case would be climate federalism, which is essentially what the Paris Agreement represents. Even if the most recent meeting about the agreement—COP25 in Madrid, in December 2019—had been more successful, many barriers and limitations to significant change would remain.

The most recent work bringing together complexity, climate change and policies appears to be from Roland Kupers, who co-authored a book about complexity and public policy with David Colander (Colander & Kupers, 2014). In January of 2020, he presented at the Santa Fe Institute in New Mexico, previewing his forthcoming book on climate change and policy (Kupers, 2020b, 2020a).

Colander and Kupers (2014) explain public policy in the context of complexity as follows:

> Policy decisions are a part of an evolving set of decisions being made in a complex evolving

> system. Any decision made at a point in time builds on an unfolding set of decisions made in the past, and will have unknown consequences for future decisions. It is being made with far from perfect knowledge. Complexity policy provides broad options, and ideas for creative new directions in policy, not precise policy recommendations. (p. 44)

They describe three approaches to policy formation that parallel those from the Center for Climate and Energy Solutions and compare them to parenting styles. The rule-driven, top-down control by government is heavily authoritarian. The second is a market fundamentalist approach, which is essentially "hands-off" and lets development happen on its own. The third, for which they advocate as the true alternative to top-down control, they call a laissez-faire activist approach. This focuses on general guidelines for influencing development, along with positive role models. Using a framework of complexity, the development happens within an environment where everything continues to evolve and change. As Colander and Kupers (2014) specifically define it:

> Activist laissez-faire policy is a bottom-up policy within which people help solve problems as efficiently as possible through voluntary, collective, and cooperative self-imposed modification of their selfish impulses. (p. 60)

Rava (2021) addressed the development of policies for complex issues through the perspective of design, which he describes as a systems approach to policy design. He connected this, historically, to Özbekhan's (1968) general theory of planning. A situation is problematic when there is dissonance between the situation and the value system in question. Such problems are also recognized as "wicked problems" or "messes."

Structured problems can be solved or addressed through rational processes of negotiations. For complex problems, Rava (2021) suggested that "policy as learning" is required.

Moving Forward

If climate scientists are correct, there are urgent needs to begin addressing climate change. The timing, however, seems to remain unclear. Most targets are set for achieving net-zero emissions by 2050, with a goal of keeping the increase in global temperatures below 2 degrees Celsius. New findings and estimates are reported on almost a daily basis about current and future effects. Polar regions may be warming faster than expected, glaciers melting at accelerated rates, and permafrost releasing more CO_2 than expected.

Climate scientists have been in near consensus about most of their findings for years. Politicians and business leaders appear to be joining the ranks of believers, in growing numbers. Moving from identification to action, however, is going to require an unprecedented level of change and global cooperation. That will not happen without clear direction and planning.

One of the significant hurdles is mindset, which is not simply a matter of vested interests or lack of openness to ideas. Humans have a different sense of preservation and permanence than other animals. Nests and dens and other habitats get built and last for as long as they do, and then are replaced. Humans build and maintain and preserve artifacts with a sense that their demise is a failure. That is a part of how we determine quality and value.

That mindset expanded dramatically with the production of steel and concrete buildings, bridges, and highways; of ships and cars and airplanes; and possibly most extreme, of plastics. We have filled the biosphere with elements that do not follow the Panarchy cycle. They do not degenerate into elements with new potential. At the least, we expend extreme amounts of energy in order to "recycle" them—to find some feasible means of reuse.

The most obvious target for change is the human use of fossil fuels. It is easy to continue stating that, but as noted, we have yet to begin to change. The ramifications for every society have yet to be truly understood. It is such a monolithic issue, though, that it is easily identifiable. Basically, we need to change all end use of energy to electricity, and all generation of power (electricity) to renewable sources.

Rather than continue the litany of issues related to climate change, it might be useful to explore a more specific example. An effort is currently underway to transform the chemicals industry, to do its part in achieving the 2015 Paris Agreement goals. This is led in part through the Science Based Targets initiative (SBTi) (Science Based Targets, n.d.). The petrochemical sector is particularly complex with respect to the challenges presented by climate change. These chemicals are found in almost every part of our lives, from packaging and tires to clothing, phones, and computers; to solar panels and wind turbines; and to lighter bodies for electric vehicles.

According to a report by the International Energy Agency (2018), demands for plastics have nearly doubled since 2000, and outpaced demands for steel, aluminum, and cement. The chemical industry consumes as much energy as steel and cement, combined, but emits less CO_2. (Much of the carbon in the final products is locked in, being released later as the materials are burned or otherwise degrade.) Oil and gas account for 90% of the feedstock (raw materials) and much of the energy needed for production. As oil companies see the demand for gasoline and other traditional products drop, they more closely align with petrochemical companies as growing markets.

Under the IEA's 2050 Clean Technology Scenario targets, air pollutants from primary chemical production would be reduced by 90% and water use would decrease by 30%. Half of the 10 million annual tons of plastics going into the oceans would be stopped, and the global average collection rate of plastic waste would increase three-fold (International Energy Agency, 2018).

A webinar hosted by SBTi on February 6, 2020 outlined something of an "adoption of innovation" strategy

for recruiting chemical companies to join the initiative (SBTi, 2020). The first stage is to reduce barriers to the adoption of science-based targets (SBTs), the second to institutionalize adoption, and finally to create a critical mass of companies using the targets. Thus far, 330 companies have approved such targets, 20 companies have committed to setting SBTs, but only seven have set SBTs.

Committing to the SBTi targets includes reporting under the Scope 3 accounting standards for green house gas emissions, across the entire chain of business activities. (See Figure 5.) The corporate representative for the webinar stated that her company had voiced support for ambitious climate policies even leading up to the 2015 United Nations Climate Change Conference, or Conference of the Parties (COP21). Still, they were surprised by the effort required to comply with the SBTi targets—a 30% reduction in emissions from operations and a 28% reduction in those from the larger value chain by 2030.

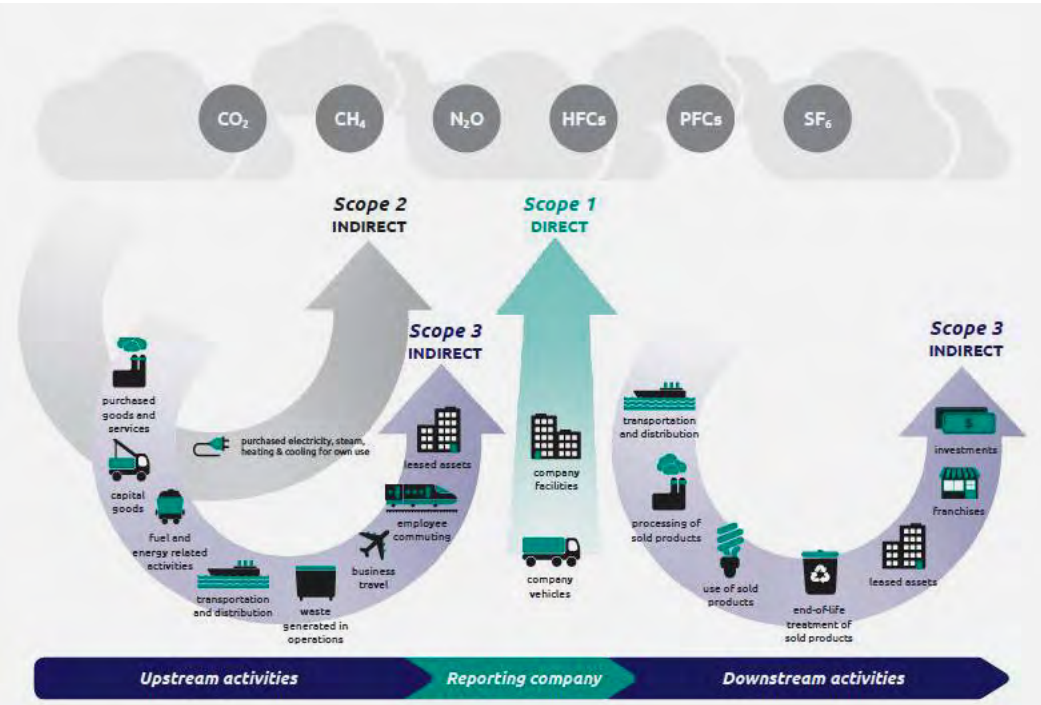


Figure 5. *Corporate Value Chain (Scope 3) Accounting and Reporting Standard*

Source: World Business Council for Sustainable Development & World Resources Institute (2011, p. 5).

The corporate representative strongly stated a need for policies. The implication was that her company not only needed guidance, it also needed other companies to be given guidance and to be held to equitable standards for the industry to meet its goals by 2050.

The petrochemical industry is arguably one of the most complex industries currently facing climate change. There are no obvious substitutes (yet) for its raw materials, and its products are needed for many of the technologies currently addressing climate change.

Taking to heart the ideas cited in this paper from Kupers, Rava, and others regarding systemic policies, setting bureaucratic mandates for change would be misguided. There are no predictive models encompassing all aspects related to climate change. As urgent as the needs are for beginning change, the process is likely to be much more like sailing a ship across a large ocean using a sextant than sending a spaceship to Mars. That is not to say that theories and models of complexity are not important. As incredible as our technologies may be, the context is one of interdependent tides and currents in dynamic flow. Every large-scale change that we make will need to be checked and corrected. We need the best of our scientists, along with corporate, political, and social leaders, to work together, developing and revising policies of cooperation and committing to goals of resilience for our planet.

The role of complexity science should be less about prescribing policies based on theories, and more about gathering data from the vast number initiatives that are, and will be, taking place. The world cannot commit to investing in every possible solution. Our best alternatives may require all the resources that we are able to garner. Complexity science can support policy development by assessing the impacts of small innovations, and finding synergies across initiatives so that, over time, we can invest in answers with the most hope. We have no time to waste.

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Complexity, Economic Inequality and Income Distribution: What Can the Vascular Network Topology and Empirical Analysis of Readily Available Data Tell Us About the End of Poverty?

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Abstract

Income distribution and inequality remain ardent issues of our time. Many scholars claim that these problems fuel today's popular revolts against the elites and a rational approach toward the development of new solutions, and that decision makers and social scientists lack new ideas and tools to defuse them. This paper favors the alternative of using a Network Theory approach, where mapping the macroscale network topology helps to understand the structure of the economic systems responsible for the creation and distribution of wealth.

Until now, mapping of the economic network topology has been the result of trial and error methods, based on intuitive assumptions, instead of a sound theoretical approach validated by data. However, the use of Network Theory has helped us understand the statistical structure of complex systems, such as genomic, proteomic, metabolomics, ecological and scientific networks. Furthermore, the combined use of Mechanical Statistics and Network Theory helps to understand the nature and features of the dual Gibbs-Pareto distribution of economic wealth.

This paper states that the ubiquity of the Gibbs-Pareto distribution relates to the natural evolution of a wide array of systems that, to survive over long periods of time, move into higher efficiency regimes. This in turn provokes the reconfiguration of these systems, into a vascular network configuration. The revision analysis shows that many vascular network arrangements can be divided in two clearly distinct phases. Most of the nodes, relate to the Gibbs partition of the distribution and are geared to maximize diffusion (e.g.

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surface contact area) adhering to the mathematical behavior of a random network. While the rest of the nodes are part of the Pareto partition of the distribution and take advantage of the economies of scale and the minimization of costs (e.g. transport of energy and materials over long distances). The empirical analysis of income distribution of more than 70 countries shows that regardless of current income distribution and inequality conditions around the world, every modern economy has the same network structure.

What appears to make the difference between the most egalitarian societies and the most unequal ones is how close or far apart are, to a simple symmetry rule where 50% of income is distributed among 80%-90% of the nodes, (the Gibbs partition), and the other 50% of the income is distributed among 10%-20% of the nodes (the Pareto partition).

The main conclusions from the proposed theoretical and data-based approach are that the economic network topology, being dependent upon efficiency of matter and energy use and distribution, evolve into hierarchical vascular arrangements that impede the abolishment of inequality. However, within this restriction it can also be said that there are degrees of freedom that allow an economic network to evolve into symmetric or "fair" and stable economies like Japan or Norway, which are closer to a 50/50 (Gibbs-Pareto) income distribution, and asymmetric, "unfair" or "depredatory" economic networks, like Mexico and South Africa, where the income distribution is closer to the 30/70 (Gibbs-Pareto) income ratio.

Keywords: poverty, complex systems, vascular network topology, network theory, Gibbs-Pareto Distribution

Complejidad, desigualdad económica y distribución del ingreso: ¿Qué nos puede decir la topología de la red vascular y el análisis empírico de los datos fácilmente disponibles sobre el fin de la pobreza?

Resumen

La distribución del ingreso y la desigualdad siguen siendo temas candentes de nuestro tiempo. Muchos académicos afirman que estos problemas alimentan las revueltas populares de hoy contra

las élites y un enfoque racional hacia el desarrollo de nuevas soluciones, y que los tomadores de decisiones y los científicos sociales carecen de nuevas ideas y herramientas para desactivarlos. Este artículo favorece la alternativa de utilizar un enfoque de Teoría de Redes, donde el mapeo de la topología de la red a macroescala ayuda a comprender la estructura de los sistemas económicos responsables de la creación y distribución de la riqueza.

Hasta ahora, el mapeo de la topología de la red económica ha sido el resultado de métodos de prueba y error, basados en suposiciones intuitivas, en lugar de un enfoque teórico sólido validado por datos. Sin embargo, el uso de la teoría de redes nos ha ayudado a comprender la estructura estadística de sistemas complejos, como las redes genómicas, proteómicas, metabolómicas, ecológicas y científicas. Además, el uso combinado de la estadística mecánica y la teoría de redes ayuda a comprender la naturaleza y las características de la distribución dual Gibbs-Pareto de la riqueza económica.

Este artículo afirma que la ubicuidad de la distribución de Gibbs-Pareto se relaciona con la evolución natural de una amplia gama de sistemas que, para sobrevivir durante largos períodos de tiempo, se mueven hacia regímenes de mayor eficiencia. Esto a su vez provoca la reconfiguración de estos sistemas, en una configuración de red vascular. El análisis de revisión muestra que muchos arreglos de redes vasculares pueden dividirse en dos fases claramente diferenciadas. La mayoría de los nodos se relacionan con la partición de Gibbs de la distribución y están orientados a maximizar la difusión (por ejemplo, el área de contacto de la superficie) siguiendo el comportamiento matemático de una red aleatoria. Mientras que el resto de nodos forman parte de la partición de Pareto de la distribución y aprovechan las economías de escala y la minimización de costes (por ejemplo, transporte de energía y materiales a largas distancias). El análisis empírico de la distribución del ingreso de más de 70 países muestra que, independientemente de la distribución del ingreso actual y las condiciones de desigualdad en todo el mundo, todas las economías modernas tienen la misma estructura de red.

Lo que parece marcar la diferencia entre las sociedades más igualitarias y las más desiguales es qué tan cercanas o distantes están, a una regla de simetría simple donde el 50% del ingreso se distribuye entre el 80% -90% de los nodos, (la partición de Gibbs), y el otro 50% de los ingresos se distribuye entre el 10% -20% de los nodos (la partición de Pareto).

Las principales conclusiones del enfoque teórico y basado en datos propuesto son que la topología de la red económica, que depende de la eficiencia del uso y distribución de la materia y la energía, evoluciona hacia arreglos vasculares jerárquicos que impiden la abolición de la desigualdad. Sin embargo, dentro de esta restricción también se puede decir que existen grados de libertad que permiten que una red económica evolucione hacia economías simétricas o "justas" y estables como Japón o Noruega, que se acercan más al 50/50 (Gibbs-Pareto) distribución del ingreso, y redes económicas asimétricas, "injustas" o "depredadoras", como México y Sudáfrica, donde la distribución del ingreso se acerca más a la razón de ingreso 30/70 (Gibbs-Pareto).

Palabras clave: pobreza, sistemas complejos, topología de redes vasculares, teoría de redes, distribución de Gibbs-Pareto

复杂性、经济不平等与收入分配：关于终结贫困，vascular网络拓朴和现成数据的实证分析能告诉我们什么？

摘要

收入分配和不平等在我们这一代仍然是热点议题。许多学者认为，这些问题加剧了当前民众对精英的反抗，推动了发展新解决方案的理性措施，并认为决策者和社会科学家缺乏新想法和工具来平息民众反抗。本文使用一项网络理论（Network Theory）方法，这项方法运用宏观网络拓扑映射来帮助理解有关财富创造和分配的经济系统的结构。

目前，经济网络拓扑映射由试错法得出，基于直观假设，而不是基于一个由数据验证的、健全的理论方法。然而，使用网络理论已帮助我们理解复杂系统的统计学结构，例如基因组网络、蛋白质组网络、代谢组网络、生态网络以及科学网络。此外，结合机械统计学和网络理论，帮助理解经济财富Gibbs分配和Pareto分配的性质和特征。

本文认为，Gibbs-Pareto分配的普遍性与大量系统的自然演变相关，这些系统为长期生存下去而出现了效率更高的制度。这反过来引起了系统重组，成为一个vascular网络配置。该分析显示，许多vascular网络安排能被划分为两个独特的阶段。大多数节点与Gibbs分配相关，并适用于将扩散（例如表面接触面积）最大化，遵守随机网络的数学行为。而其余节点属

于Pareto分配，并利用规模经济和成本最小化（例如长途运输能源和材料）。对超过70个国家的收入分配进行实证分析显示，不管全球当前的收入分配和不平等情况如何，每个现代经济都有一样的网络结构。

区分最平均主义社会和最不平等社会的似乎是，距离一个简单的对称规则有多近或多远，在这个对称规则中，50%的收入分配给80%-90%的节点（Gibbs分配），而另50%的收入分配给10%-20%的节点（Pareto分配）。

本文所提出的理论和基于数据的方法所得出的主要结论是，经济网络拓扑—依赖物质和能源的使用效率和分配效率—会演变为阶级的vascular安排，这种安排阻碍了对不平等的废除。然而，在这一限制中，也可以认为存在一定的自由度，允许经济网络演变为对称或“公平”的稳定经济，例如日本和挪威，这两国的收入分配的Gibbs-Pareto比值接近50/50，或者演变为不对称、“不公平”或“破坏性”经济网络，例如墨西哥和南非，这两国的收入分配的Gibbs-Pareto比值接近30/70。

关键词：贫困，复杂系统，vascular网络拓朴，网络理论，吉布斯-帕累托分配（Gibbs-Pareto Distribution）

The Hidden Structure of Complex Systems

Complex systems, made of many interacting components, have some general properties despite the apparent differences between them. Those properties can be described in terms of their global features, in similar fashion as gases of different compositions, have similar thermodynamic properties. Examples of complex systems are diverse, such as, cell metabolism (Zoltán & Albert-László, 2002), genomes (Adamic & Huberman, 2000), ecological and social systems (Newman, 2005). Many of these systems persist over long periods of time and evolve with structural relations that sustain their stable and predictable operation. For example, all animals and plants obey the same power law for the scale-up of metabolic activity, Q, in terms of their body mass M (Q proportional to $M^{3/4}$). This has been shown to be a consequence of the principle of energy minimization for the circulation of fluids within such living organisms (West, Brown, & Enquist, 1997).

Many complex systems are currently modeled as networks of agents (nodes or vertices) connected with each other with physical or logical connections (edges) that are subject to geometrical and physical constraints, such as the maximal average connectivity,

k, between a finite number of nodes. Following this logic, Kauffman (1969) showed that random binary genetic networks, modelled by Boolean logic functions, need to limit their average connectivity to a rather low value, $2 < k < 3$. Otherwise, the number of logical operations will be trans computational, meaning that no computer will be able to compute all operations in a finite period, because the number of connections follows a double exponential function on k. This has been corroborated in the *E. coli*, regulatory network (Thieffry, Huerta, Pérez-Rueda, & Collado-Vides, 1998). Analysis of the connectivity of metabolic networks of 43 different organisms, where substrates are nodes and reactions or regulatory interactions are edges, showed the conservation of very few highly connected hubs, together with the coexistence of a large majority of low connectivity nodes (Kauffman, 1969). This was explained as an evolutionary constraint to conserve the topological length of each network diameter or shortest path between the most distant nodes of the network, despite the increase in the size and complexity of the metabolic system (Jeong, Tombor, Albert, Oltavi, & Barabasi, 2000).

Hence, there are physical and computational constraints for the evolution of complex networks forcing the coexistence of two kinds of interconnected systems. For example, a small number of nodes with many connections (cliques) that follow a power law distribution (Pareto) of their average number connections (k much larger than 3) and a large number of nodes, each with very few connections ($k = 2$) following a random or exponential distribution (Gibbs-Boltzmann = Gibbs). The existence of cliques helps to explain the so called "small world" (Miligram, 1967) (Watts & Strogatz, 1998), behavior where any node can communicate to any other node by very few relays. The linkage between the Pareto and Gibbs subsystems requires the existence of tree-like structures where few "generals" control a large number of "soldiers" by means of a hierarchy of different levels of small operating units or cliques. Again, there are topological and functional restrictions to the size of cliques related to the computational (cognitive) capacity of the neocortex of primate species including human beings (Dunbar, 1992; Kudo & Dunbar, 2001).

Another significant example of unequal distribution is the 90:10:1 rule of unequal participation in social media and online communities observed by Jakob Nielsen. According to Nielsen, 1% of content generators in social media, contribute with 90% of publications, 9% contribute with 10% and 90% of users produce no content at all (Nielsen, 2006). Also, the relative distribution of family income available in all world economies can be seen in Figure 1. In an average of 71 countries, 80% of households have access to 54.28% of the total income, while the superior 20% (deciles 9 and 10) have access to the remaining 45.72%, with very marked differences such as South Africa, where 80% of the population has access to only 33.83% of the income. In Norway, the same percentage of the population has access to 64.44% of available income (Euromonitor International, 2013).

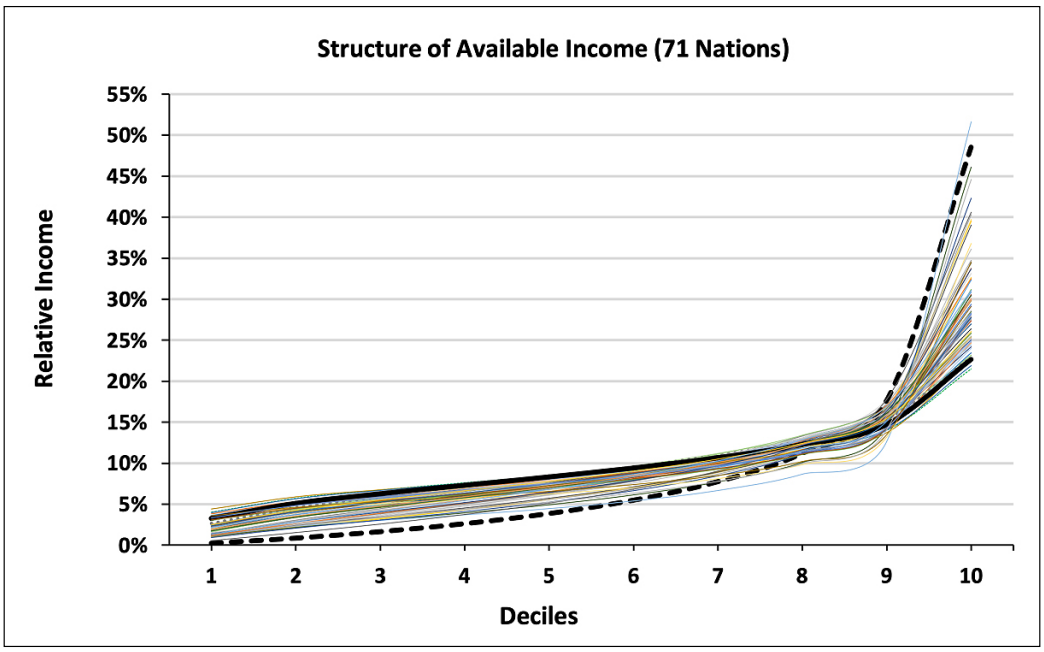

Figure 1. *Relative structure of family income by deciles in 71 countries (2011).*
Source: World Consumer Income and Expenditure Patterns 2013, Euromonitor International.

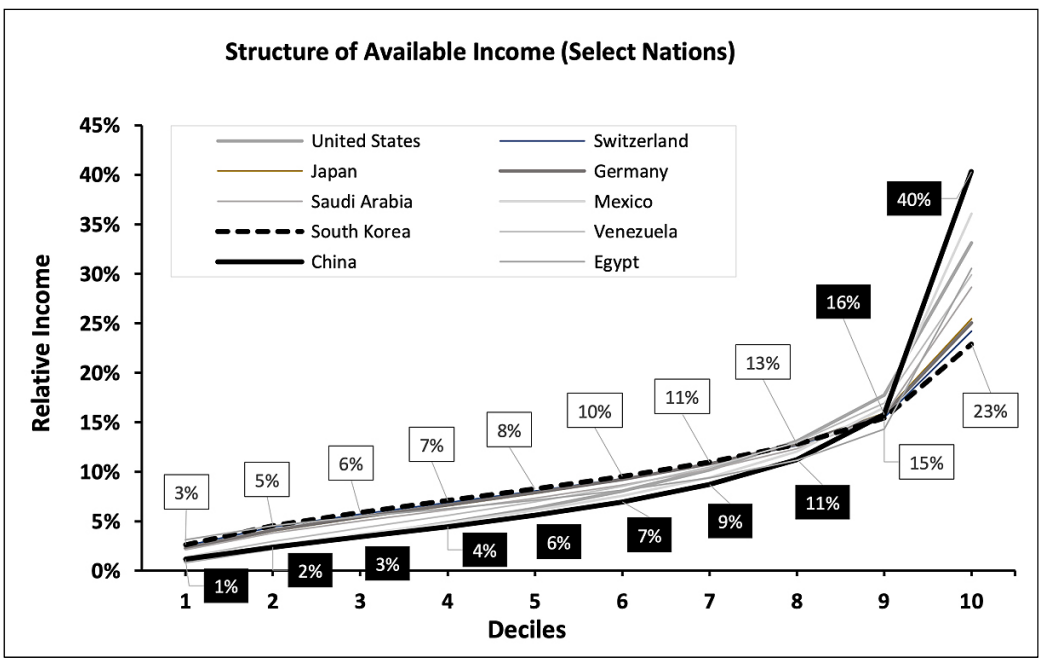

Figure 2. *Relative distribution of family income by deciles in selected countries (2011).*
Source: World Consumer Income and Expenditure Patterns 2013, Euromonitor International.

The above-mentioned data mean that the distribution of attributes, resources, and opportunities in human societies has a structure like that of the abundance of species in a habitat with segments that differ significantly among themselves:

1. Approximately 90% of the population follows the exponential random distribution (Gibbs partition).
2. An intermediate segment, closer to 9% of the population, follows a power law with a moderate slope of the Pareto partition.
3. A superior segment, closer to or lower than 1%, follows a steeper slope.

Although all societies are structurally or topologically similar—many people having too little and very few having a lot—small differences in the network's configuration, may transform the evolutionary configuration of systems and their conditions of stability and turbulence. Networks with remarkably high disproportions between Gibbs and Pareto distributions are highly unequal and tend to be turbulent and unstable in the long term (Viniegra, 2018). In considering the relative distribution of available income in a group of selected countries as shown in Figure 2, we observe that an apparently small difference, such as the first decile only having access to 1% of available income in countries like Mexico or Egypt while the same decile gains 3% of income in Switzerland or South Korea, is linked with radically different conditions of development, stability, and growth.

A proposal, coherent with the disparity between Gibbs and Pareto distributions, was made by Jeffrey Sachs (2006), who estimated that extreme poverty can only be mitigated when people can pay for the minimum consumption needed for their survival and have the capacity to save (λ) and reinvest their surplus. This is the same idea behind the microcredit programs that Grameen Bank in Bangladesh began in 1983 and that have now expanded around the globe. Despite some generated benefits, these programs have also been the objects of criticism because several financial institutions have abused theme by setting annual interest rates higher than 100% (Gómez Gil, 2016). Apparently, the simplistic approach that assumes credit will have a direct impact on poverty without realizing the high risk for small new micro businessmen who lack necessary technical and commercial capacities (access to the Pareto distribution) that reduces the failure rate and the cost of money. In other words, the micro-credit approach does not consider the overarching relationship that prevents the development and integration of micro companies to the Pareto subsystem. That integration can be an important factor for reconfiguring the network topology and transforming it into a more economically democratic structure. This observation raises the importance of interactions and the micro-macro integration in the structure and the functioning of the social networks.

One example that illustrates the large systemic effect of the micro-macro relationship is Mexico. When transfer-

ring South Korea's income distribution to the income level in Mexico as shown in 1, we observe a radically different situation. It suggests that although complex systems operate within immovable physical restrictions, such as the need to generate vascular networks to take advantage of economies of scale, the degrees of freedom in social systems are sufficiently broad to reach completely dissimilar configurations.

Table 1. *Income Available in Mexico Compared with Income Distribution of South Korea*

Deciles	% México	% South Korea	Income in México (USD/ year)	México as South Korea (USD/ year)	Income in México (monthly pesos; USD 20x1)	México as South Korea (monthly pesos; USD 20x1)	% Change
1	1.19%	2.64%	$3,227	$7,158	$5,378	$11,929	122%
2	2.54%	4.57%	$6,902	$12,398	$11,503	$20,663	80%
3	3.68%	5.89%	$9,998	$16,000	$16,663	$26,667	60%
4	4.84%	7.09%	$13,129	$19,240	$21,881	$32,066	47%
5	6.10%	8.27%	$16,557	$22,452	$27,595	$37,419	36%
6	7.58%	9.53%	$20,567	$25,868	$34,279	$43,113	26%
7	9.44%	10.96%	$25,622	$29,767	$42,704	$49,612	16%
8	12.05%	12.76%	$32,710	$34,646	$54,517	$57,744	6%
9	16.51%	15.40%	$44,816	$41,822	$74,693	$69,704	-7%
10	36.09%	22.89%	$97,978	$62,156	$163,297	$103,593	-37%
	100%	100%	$271,506	$271,506	$452,510	$452,510	

For example, if Mexico changed overnight and became a nation as economically democratic as South Korea in terms of education, health, credit, justice, and economic competition, but without a variation of its income level, 80% of families would have higher incomes (122% more in the case of the first decile), while the two highest deciles would have lower income (-7% and -37%, respectively). However, they would not lose their position of supremacy in the social hierarchy. In turn, that would probably reduce violence and social instability and demolish decades of economic stagnation.

Before reaching any hasty conclusions, it is worth noting that current available income measurements reflect the status of evolved structures. That is, the Korean and Norwegian people reached current income distribution because the sum of their behaviors construed a different strategy from that of the South African, Mexican, and Egyp-

tian people. Therefore, it is not likely that "Robin Hood" type, redistributive-only solutions will change the network topology and the income distribution by decree. In fact, the discussion is broader and has to do with the way in which both the Gibbs and Pareto partitions of the distribution interact with each other.

Constraints on the Partition of Gibbs and Pareto Networks

As stated above, this short overview of complex social networks shows the Gibbs-Pareto distribution coupling, suggests the coexistence between few strongly connected cliques and many loosely connected peripheral nodes whose relative proportion has been analyzed in 67 countries (Tao et al. 2019). They found that nearly 90% of loosely connected nodes (k = 2) follow an exponential law (Gibbs-Boltzmann-Maxwell) derived by Erdős (Erdős & Rényi, 1960) and 10% of preferential and tightly interconnected nodes, follow a power function (scale-free) or Pareto law (Levy & Solomon, 1997). Mechanistic analysis of Gibbs distribution has been shown to be equivalent to the molecules (nodes) in a fluid interacting at random with each other and they seem to be the building blocks of economic equilibrium in a similar fashion to random chemical processes (Tao, 2015). Similar analysis of Pareto law has been shown to be based in the cooperative behavior where the probability of making new connections is a growing function of the previous number of such connections (Barabasi & Albert, 1999). This behavior is reminiscent of other power laws such as the Freundlich isotherm used in chemical engineering. The whole economic model can be seen as a system made of two phases where the critical variable blocking or helping economic agents to go from one phase to the other is the saving propensity. That is, following Sachs (2006) ideas, subsistence economic units need to accumulate a critical surplus to reinvest in their productivity in order to move up from the Gibbs random network subsystem to the cooperative Pareto subsystem (Chakraborti & Chakraborti, 2000). Once they reach the critical level, their outcome is strongly corelated to profits, giving rise to strong inequality where the rich become increasingly richer. However, to the best of our knowledge, there has not been an attempt to define an empirical law on the relative participation of Gibbs and Pareto distributions in the total income distribution curve and this is the matter of present work.

Basic Empirical Equations of Gibbs and Pareto as Related to Lorenz Curves

A convenient way to analyze the connection between Gibbs and Pareto subsystems is to study Lorenz distributions where the fraction of total cumulated wealth, L(x), is given in terms of the fraction of the cumulated population having access to such income P(x). This method allows the plot L(P,x) vs. P(x) to provide a way to estimate the inequality index, (Gini index) where G = 0 corresponds to complete equality (all people have the same income) rep-

resented by the straight line L = P for all levels of income, x. The other extreme condition is G = 1, in which only one person has income. Those extreme values are not observed, and the Gini coefficient is in the range, 0.2 < G < 0.7. The functions L = L(P) for Gibbs and Pareto distributions have been summarized (Arcagni & Porro, 2014) and will be reviewed briefly. Here, we propose that the Gini coefficient provides indirect information on the relative permittivity between Pareto and Gini distributions, a high G is equivalent to high connectivity, k, and, vice versa, low G is equivalent to low average connectivity (k 2).

In this work, a mathematical analysis is performed on the feasibility and significance of linking the two subsystems (Gibbs and Pareto) by properly adjusting a new parameter of proportionality, K, that estimates the participation of the Gibbs function as compared to the Pareto function within the range 0 < P < 1, that is within a given fraction of the total population. A discussion, based on a review by Arcagni & Porro (2014), is presented here to help analyze the significance of how the parameters, a and K, are related to each other and with the overall distribution of wealth, measured by the Gini coefficient.

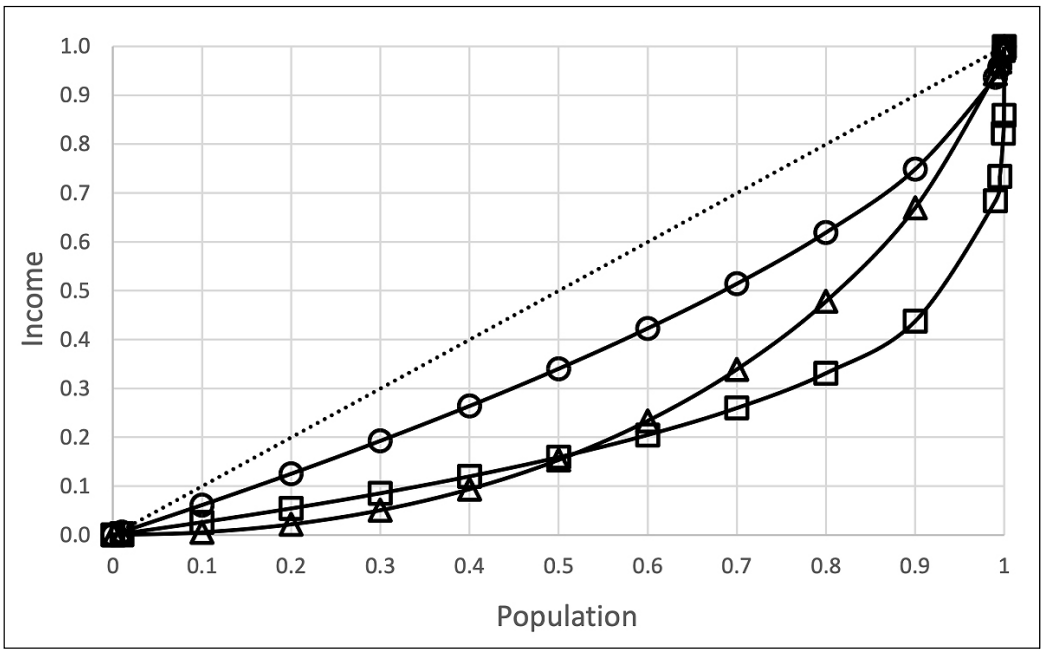

Figure 3. *Comparison between Gibbs (Triangles; G = 0.5) and two Pareto distributions corresponding to G = 0.60 (Squares; P* = 0.50) and G = 0.25 (Circles, P* = 0.98). Dotted lines correspond to the equilibrium condition (G = 0).*

Pareto distribution in terms of wealth, x, follows the power cumulative function, P (x) as shown in Equation (1):

$$P(x) = 1 - e^{-x/\theta} \qquad (1)$$

Where, the scale factor, q, provides a way to calculate the necessary wealth, x = qln2, to attain half the value, P = ½. The Lorenz curve is given by Equation (2):

$$L(P) = P + (1 - P)ln\,(1 - P) \quad (2)$$

The Gini coefficient, G, is calculated in Equation (3) to have a fixed value of G = ½, from the integral

$$G = 1 - 2\int_0^1 L(P)dP = 1/2 \quad (3)$$

It is important to notice that Gibbs distribution has a fixed value, G = 0.5 and for that matter it cannot explain by itself the observed differences on the Gini coefficient. Therefore, adjustment of G should come from the connection between Pareto and Gibbs distributions. Pareto distribution, as shown in Equation (4), is calculated in terms of wealth, x, and follows the exponential cumulative function, P (x):

$$P(x) = 1 - \left(\frac{x_m}{x}\right)^a \quad (4)$$

Where, the scale factor, x_m, is the minimum permissible value of x, and together with a, provides a way to calculate the necessary wealth, x = $x_m(1/2)^{-1/a}$, to attain half the value, P = ½. The corresponding Lorenz curve is given by Equation (5):

$$L(P) = 1 + (1 - P)^{1-1/a} \quad (5)$$

The Gini coefficient, G, is calculated by using Equation (6):

$$G = 1 - 2\int_0^1 L(P)dP = \frac{1}{2a-1} \quad (6)$$

with the Gini coefficient in the range, 0 < G < 1, and meaning that a > 1.

A comparison between Pareto and Gibbs distributions, plotted as Lorenz curves, is shown in Figure 3. If the two L(P) functions, defined by Equation (2) and Equation (5) intersect when P* = 0.5, it is assumed that half the population follows each of those distributions. In such a case, Pareto coefficient takes the value a = 1.32. For P* = 0.98, the value of the Pareto coefficient is a = 2.5. Equation (6) concludes that Gini coefficient of Pareto distribution, is a decreasing function of a, attaining a complete equality (G » 0) when a, is much larger than 2.

The estimation of Gini coefficient, a, at the intersection can be obtained from Equation (7) obtained by equalizing Equation (2) and Equation (5):

$$P* + (1 - P*)\,ln(1 - P*) = 1 + (1 - P*)^{1-1/a} \quad (7)$$

From Equation (7) the value of a is calculated in Equation (8):

$$a = -\frac{ln(1-P*)}{ln[1-ln\,(1-P*)]} \quad (8)$$

Now, if the Gibbs and Pareto distributions link or connect at one value of the distribution, P(x), it is necessary and sufficient to have a solution of Equation (7) for 0 < P* < 1. Figure 4 shows a plot of the calculated values of, a, as a function of P* indicated in Equation (8) in the permissible range, 0 < P < 1. In such a plot, the estimated value of a increases with P* which refutes the idea that inequality (low values of a) should increase with P* (larger fraction of population in Gibbs distribution), and such a relationship contradicts the strong evidence that P* » 0.9 (Drăgulescu & Yakovenko, 2001; Tao, et al., 2019). Therefore, linking Gibbs and Pareto function require special care to satisfy such constraint on P*. A possible solution is to reinforce (or weaken) Gibbs distribution by defining a weighting factor, K, as shown in Equation (9):

$$K = \frac{1-(1-P)^{1-\frac{1}{a}}}{P+(1-P)ln(1-P)} \quad (9)$$

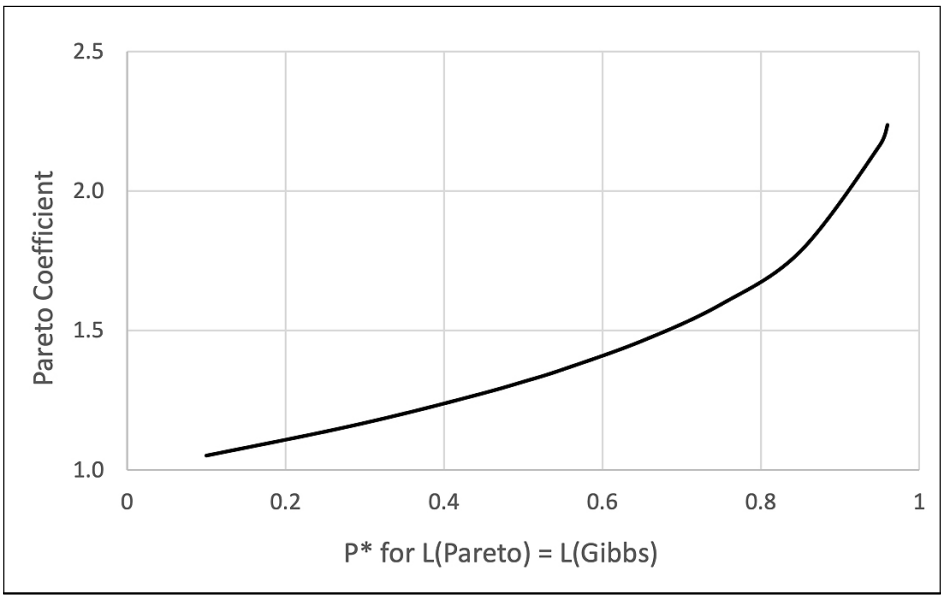

Figure 4. *Calculation of the Pareto coefficient, a, as a function of the intersection P* at which L(Pareto) = L(Gibbs)*

This assumption follows from the idea that the combined Lorenz plot is partitioned in two sectors of the population. For P > P*, the Pareto distribution holds, but otherwise, the Gibbs distribution would hold, reinforced, or weaken by a weighting factor, K.

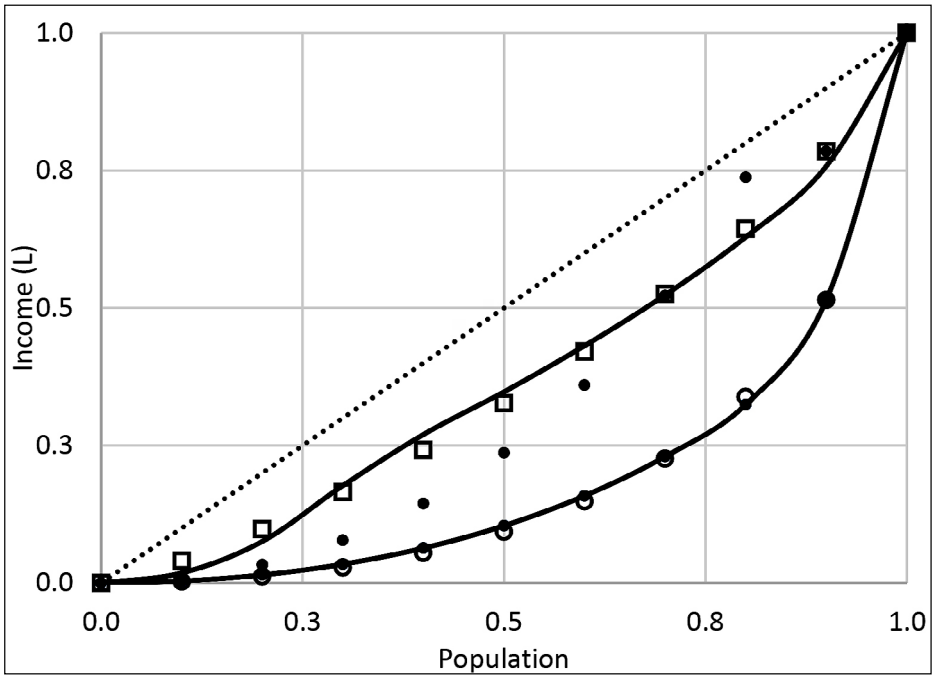

Figure 5. *Lorenz curves for South Africa (squares, G = 0.62) and Norway (circles, G = 0.25) Hypothesis 1, fixed P* = 0.9 (small dots) and Hypothesis 2, adjustable P* (interrupted line). See details in the text. Data source: Euromonitor International. (2013).*

Figure 5 shows the cumulative income fraction (L) versus the cumulative population fraction (P) reported on 2011 by Euromonitor International (2013) for South Africa and Norway. Continuous Lorenz curves for each set of data, were calculated by the minimization of the sum of squared errors, S, given in Equation (10):

$$S = \sum(L_{calc} - L_{obs})^2 \qquad (10)$$

Where, L_{obs}, is provided by the available income data and L_{calc} is defined by Equations (11a) and Equation (11b):

$$L_{calc} = 1 - (1 - P)^{1-\frac{1}{a}}; \forall, 1 > P > P* \qquad (11a)$$

$$L_{calc} = K[1 - (1 - P)\, ln(1 - P)]; \forall, P* \geq P > 0 \qquad (11b)$$

Two alternative hypotheses were tested:

1) A fixed, P* = 0.9, supported by empirical evidence (Tao, et al., 2019), and

2) A variable, 0 < P* < 1, as an alternative hypothesis to check the sensitivity of the model with respect to parameter P*.

Table 2 shows the results of those calculations. For South Africa, there were not significant differences between those hypothesis and P* = 0.9 was the best choice with K < 1 and a < 2. For Norway, there were significant differences between hypothesis with best fit for P* = 0.34, K > 1 and a > 2. These calculations shown that for the case with larger inequality, most of the population was in the Gibbs network (P* = 0.9) and the Pareto network showed high inequality since it was closer to unity where inequality was maximal (see de exponent in equation 11a). For Norway, the fit was sensitive to the value of P* = 0.34, suggesting a much higher incorporation of the population to the Pareto network and with a larger pareto coefficient, showing much less income inequallity. Coefficient K was higher than unity, suggesting a better participation of Gibbs network in the distribution of the income. Apparently, there is a parallel interaction between, a and K. That is, higher inequality within the Pareto network (lower a) leads to a larger participation on income distribution by Gibbs network with lower share (K < 1) in the total distribution of wealth. Conversely, a lower inequality in the Pareto network (higher a) leads to a smaller participation on the income distribution by Gibbs network but with larger share (K > 1) in the total distribution of wealth. Altogether, it seems that the rules that control the Pareto distribution (modulation of a) control the fraction of people that have access to the Pareto network, which according to Sachs (2006) and Chakraborty and Chakraborty (2000) are related to the obstacles to have savings that can be reinvested in local productivity.

Table 2. *Parameters obtained by fitting combined Lorenz curves to income distribution data presented in Fig. 5.*

Country	South Africa		Norway	
P*	0.90	0.88	0.90	0.34
K	0.68	0.68	1.54	3.52
a	1.46	1.46	3.00	2.60
Chi^2	5.71E-03	5.83E-03	0.4796	0.0871
R^2	0.9986	0.9986	0.9761	0.9935

The Complexity-Public Policy Chasm

The main result of this work is the method that describes the connection between Pareto and Gibbs economic networks in terms of a weighting factors, a and K, that is reminiscent of the conductivity or permittivity between two electrical networks, constrained by the inequality of the Pareto network. A method was developed to estimate K in terms of the Gini coefficient, G, as a parameter that helps follow real data on income distribution given by Lorenz curves. If K is larger

than unity, it would mean that economic flows favor the Gibbs network or the people with lower income belonging to 90% of the population. Otherwise, the terms of trading will be in the reverse direction.

It is interesting to note that many similar papers at this point of the discussion often try to make the connection between the complexity science data analysis to a real world problem, and usually pick up any of the many, readily available, theoretical constructs from the social sciences. Usually the one chosen fits best to the obtained results (confirmation bias). However, we think it´s better if we start the discussion by centering it on the "elephant in the room". Our revision shows that in the last fifty years, a growing body of knowledge describing the structure, geometry and the restrictions that shape social and economic systems, has been brought forward by a diverse set of scientists coming out from a varied set of fields of science. A general conclusion could be the need to relate the behavior of economic systems in terms of the relative flows of energy and information but based on empirical and sound restrictions, such as the empirical law of 90% of Gibbs (random walk) network and 10% Pareto (scale-free) network. Such type of partition has been rationalized in terms of the need to maintain low average connectivity ($k \approx 2$) to assure fast enough control circuits within the network, but the persistence of small and prominent super hubs (cliques) through history has been related to the need to maintain short number of relays (network diameter) within the whole network. Thus, inequality appears because of network functionality and topology beyond the ideological or political convictions prevalent in any given society. But the degree of inequality is also important to relate measurable economic parameters that may be related to physical properties such as the relative flows of energy (energy intensity) and information (use of internet).

Unfortunately, the chasm that spans from complex systems science and day-to-day economics is so wide that it makes exceedingly difficult to understand the practical alternatives for real world problem solving, such as poverty and social instability. For example, the problem of poverty is a result of negative balances on the relative value of goods and services between a part of society and the rest of the economic and social system. Therefore, it may well happen that a well-spirited solution, such as providing strong subsidies to the poorest may not work well, if the terms of exchange of goods and services do not favor savings that can be invested on the increase of productivity. Thus, a community or a fraction of a network, can be seen as a reactor where inputs and outputs are measured but, more importantly, where the pathways to sink, maintain or regenerate wealth are understood. An interesting case is the one about first quintile in Mexico (lowest earning 20% of the population) that survive in part thanks to the remittances sent by migrants living in U.S. During the last 20 years, such remittances have amounted to nearly 80% of the annual value of Direct For-

eign Investment (DFI) but show negligible impact on the country's GDP. Detailed analysis on the fate of such remittances has shown that nearly half of them are spent on paying high interest debts, purchasing beer, soft drinks and industrialized junk food (BBVA Research, 2019). Given that some communities have started to rethink their situation and have initiated activities aimed to reinforce their local economies by means their available resources, the main thrust of federal policies has been in the direction of reinforcing existing consumption patterns that maintain poverty beyond the growing inflow of remittances. In this context is informative to compare countries such as South Korea and Mexico (Viniegra & Viniegra-González, 2012). In South Korea, the main route to decrease poverty has been the development of value chains that distribute work and wealth between small and large industries and by means of productivity gains that translate into better market competitivity, making South Korea's workers more affluent and moguls even richer and more respected around the world. Forty years ago, industrial wages in Mexico and South Korea were both around $2 USD per hour. Nowadays, Korean industrial wages are close to $15 USD per hour and Mexican industrial wages remain below $3 USD per hour, even though Mexican automotive assembly lines now produce nearly four million vehicles per year.

In conclusion we have shown that network theory approach can help us understand economic processes based on the analysis of income distribution curves by looking at parameters, a and K, that interact with each other affecting the relative participation of Gibbs and Pareto networks on the total income. We have also discussed some examples to illustrate how those ideas can be applied to the analysis of economic inequality as related to the flows of money, energy, goods and services.

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Book Review: Hilton L. Root's *Network Origins of the Global Economy: East vs. West in a Complex Systems Perspective*

Liz Johnson
Complex Systems Institute, UNC Charlotte

Hilton L. Root, *Network Origins of the Global Economy: East vs. West in a Complex Systems Perspective*. Cambridge University Press, 2020. ISBN 978-1-108-48899-0.

Academics in the realm of economics, international relations, and public policy have not yet reached the point where they need to be in relation to how the process of change and interaction patterns transpire, but they do recognize that relationships matter, whether at the macro, meso, or micro level. However, Dr. Root with his new book on *Network Origins of the Global Economy East VS. West in a Complex Systems Perspective* demonstrates that networks can pave the way to understanding and novel insights. He recognizes that networks, which are the glue that hold social and economic systems together with measurable structural characteristics, are an important aspect of the global economy.

Further, Root's approach supports the premise that one cannot understand the complexity of an entity, like the global economy, until one maps out and grasps the network behind the system over time. Root does this with provocative originality by situating political economics in the contextual perspective of complexity, while analyzing historical regimes, and addressing the coming instability in globalization due to denser connectivity yielding new sources of unpredictability. There is no perfect accounting for complexity in policy research or in life and as Pagels (1988) states, "Life can be so nonlinear" (p. 71). It is difficult for the human mind to fully grasp what is going on with the complexity of the global economy. Yet with complexity, Root presents deep logical structures that would otherwise be hidden enabling comprehension of networks and how they impact global change.

Root has an impressive background as a policy specialist in political economy and international development. He serves as policy advisor to the Asian Development Bank, the International Monetary Fund, the World Bank, the U. S. State Department, U. S. Treasury Department, U. S. Agency for International Development, and the Organization for Economic Cooperation and Development. He is also a faculty member at the George Mason University Schar School of Public Policy and Government.

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A major goal of economic research should be advancing scientific inquiry toward achieving greater understanding of the interconnected systems replete with complexity. Yet, there is still a major research focus in political economics on equilibrium, which tends to ignore bottom-up process of self-organization. Yet what is our role as researchers, and how should we connect with complexity's connectivity? The author effectively employs a new approach of complexity economics. The complexity paradigm and qualitative inquiry, through case studies over time, highlight the combined potential in research…we can now strive toward. Furthermore, how one rationalizes the context of the problem can serves as a symptom of the real problem, causing an inability to address the whole problem and improve outcomes. To address effectively a problem like how to usurp China's growing dominance in the global market, researchers need to know what the contextual factors are, how they interrelate, and whether, in fact, they facilitate or impede change.

As Arthur noted in the book's preface, the architectural structure of an economic network structure, whether centralized like China or decentralized like the west, "determines much of a systems outcome." This is not to say that systems are deterministic, given shocks can result from seemingly innocent events that transpire due to systems' sensitivity to initial conditions. So, Sullivan's "form follows function" maxim holds for economies that are conceptualized in complexity terms as "a network of networks" with feedback loops that process information with survival dependent upon network properties. The author states the purpose of this book is to inspire researchers to examine and study the origins and actions of network structures to capture more of the nuances in the economic and social world. Also, a main tenet is that network structure in which global capitalism evolves will be "radically different from the environment in which it first triumphed" (p. 264). Additionally, there needs to be more attention on the differences of network typology that can upset the balance between local adaptability and internal order.

To support claims of "economies as networks of networks" the book is organized into three parts. First Part I covers an overview and description of the political economy and complex systems. The section addresses critical subject areas like the *Great Transition in Economies History*, *Self-Organization in the Economy*, and *Human Evolutionary Behavior and Political Economy*. Part II provides a detailed and intriguing analysis of regimes from a network perspective. Major chapters included are *Network Assemblage of Regime Stability and Resilience in Europe and China, Emergence of Law from Feudalism to Small-World Connectivity*, and *Network Foundations of the Great Divergence*. Finally, Part III predicts the coming instability. For example: *Has the Baton Passed to China, China's Ambitions and Future of the Global Economy, Global Networks Over Time, A Future of Diminishing Returns or Massive Transformation, and Network Structure,* and *Economic Change: East vs. West*.

A major strength of the text is the author's grasp of complexity and application in a way that engenders questions. For example, what have I been missing as a researcher when only considering institutional structures and equilibrium in relation to studies in economics and evolution of the global economy? How one rationalizes the context of the problem can serves as a symptom of the real problem, creating an impasse to address the whole problem and improve outcomes. For example, to address effectively a problem like how to usurp China's growing dominance in the global market, researchers need to know what the contextual factors are, how they interrelate, and whether, in fact, they facilitate or impede change.

The author provides a compelling means to understand how agents self-organize and then how they continually use feedback to produce emergent behavior in the interrelating environment. This context provides *what* and *how* descriptions, along with *why* and *how* explanations regarding application. Systems adapt, possess memory, and have history, which impact the system's behavior. So, the challenge is presented as to discover what connections exist, what connections should be developed, and what resources to apply where, when, and how to achieve the internal capacity to develop and effectively use connections.

Additionally, the author presents simplistic but eye-opening conclusions with more than ample data from case studies. For example, the world is ordered by institutionalized highly skewed small world connected networks. Small world networks are costly resource-wise to establish yet enable society security and helps reduce violent transitions of power. Yet compromised are equality and basic human needs (p. 277). Additionally, the east and west serve as examples of the major influencing small world networks that dominate the global economy yet with divergent civic values. The western model allows for differences and dissonance among citizens while encouraging individual achievement. In contrast, the Chinese model is based on all citizens obeying the state with seeming equality implied. The main lesson, no matter the network, is the denser a network becomes the more sources of unpredictability arise. Further, the author's work can add considerably to the study of economics and industrial relations. First a macro perspective reveals features different from the micro level. Cogent arguments are made about how self-organization was behind the great transformations. Thus, I am persuaded that large-scale economic changes need to be at the heart of analysis in economics and play a critical role as a new model of human progress.

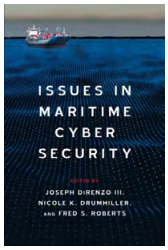
Yet no model is perfect. The claim is made that more cooperation is needed to solve global problems. Though, how does knowing a network typology enable effective analysis on how relationships can be repaired, and trust built? Much of economic theory seems to be based on a win-lose paradigm with game theory a central tenet. How can humans enjoy substantial progress

if human flourishing is not considered and there is always a loser? So, we are getting closer to knowing when and why economic systems emerge and how they can be sustained. Page stated that complex adaptive systems can influence almost everything but control almost nothing. So, complexity and ambiguity go together given there is no way to control systems. It would seem the best we can hope for is to use the author's insights on networks to harness the potential of complex systems with values of equity and potential in all humans.

The inspiring nature of the author's research of multilevel dynamics opens fertile avenues future research. For example, the author suggests the following: Why was World War I unavoidable in Europe, despite the high degree of intermarriage among royal houses? What might a network structure become maladaptive over the long term, despite properties of stability and resistance? I would add what impact will the global pandemic have on network structures and how can our knowledge about networks quell authoritarians that deny human rights?

This book is appropriate for those well-versed in complexity and those with an interest. Whereby, complexity terms can be a bit overwhelming for novices, the author does a superb job explaining terms simply. Then he provides examples for added understanding. This text can serve as a guide for policy makers and spur on researchers to push beyond their comfort levels. Finally, the text should be used in graduate programs in economics, industrial relation, and public policy to account for the economies as complex adaptive systems.

Featured Titles from Westphalia Press



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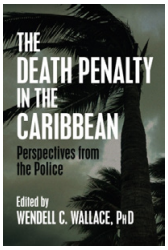

Two controversial topics, policing and the death penalty, are skillfully interwoven into one book in order to respond to this lacuna in the region. The book carries you through a disparate range of emotions, thoughts, frustrations, successes and views as espoused by police leaders throughout the Caribbean

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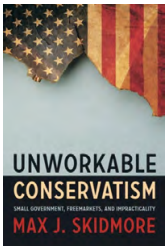
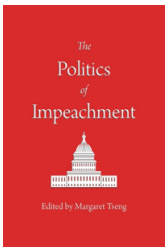


Unworkable Conservatism looks at what passes these days for "conservative" principles—small government, low taxes, minimal regulation—and demonstrates that they are not feasible under modern conditions.



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Demand the Impossible: Essays in History as Activism
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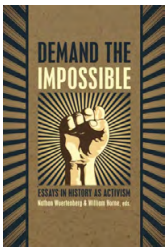
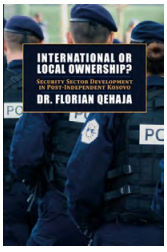


Demand the Impossible asks scholars what they can do to help solve present-day crises. The twelve essays in this volume draw inspiration from present-day activists. They examine the role of history in shaping ongoing debates over monuments, racism, clean energy, health care, poverty, and the Democratic Party.



International or Local Ownership?: Security Sector Development in Post-Independent Kosovo
by Dr. Florian Qehaja

International or Local Ownership? contributes to the debate on the concept of local ownership in post-conflict settings, and discussions on international relations, peacebuilding, security and development studies.

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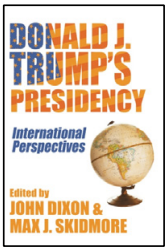
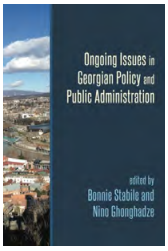


President Donald J. Trump's foreign policy rhetoric and actions become more understandable by reference to his personality traits, his worldview, and his view of the world. As such, his foreign policy emphasis was on American isolationism and economic nationalism.



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Thriving democracy and representative government depend upon a well functioning civil service, rich civic life and economic success. Georgia has been considered a top performer among countries in South Eastern Europe seeking to establish themselves in the post-Soviet era.

Poverty in America: Urban and Rural Inequality and Deprivation in the 21st Century
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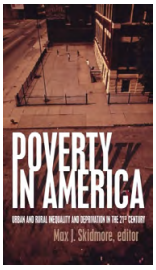

Poverty in America too often goes unnoticed, and disregarded. This perhaps results from America's general level of prosperity along with a fairly widespread notion that conditions inevitably are better in the USA than elsewhere. Political rhetoric frequently enforces such an erroneous notion.

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