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Complexity and Paradigm Change in Economics

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COMPLEXITY AND PARADIGM CHANGE IN ECONOMICS

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Abstract

Since the first volume in this series (Anderson, Arrow & Pines, 1987), a variety of scholars have claimed that complexity economics presents a fundamentally different and more scientifically grounded way of explaining and modelling the economy than more traditional perspectives. Looking back at over thirty-five years of development in the field, this essay argues that complexity economics is not merely an alternative and advantageous set of methods for understanding the economy but could play a critical role in the construction of a new economic paradigm. Complexity economics is part of a broader interlocking set of ideas—an "ontological stack"—that has the potential to supplant the dominant economic paradigms of the twentieth century. The development of such a paradigm would have major implications for economic policy and politics. The essay concludes with a discussion of what can be done to advance the complexity economics agenda and how such a paradigm might be developed.

1. Introduction

Research fields often have founding mythologies. In the case of complexity economics, the origin story usually starts with a ten-day meeting that was held at the Santa Fe Institute (SFI) in 1987. While the intellectual roots of complexity economics are deep and varied—ranging from Thorstein Veblen famously asking, "Why is economics not an evolutionary science?" to Friedrich Hayek's insights on economic self-organization, and Thomas Schelling's pioneering agent-based model of housing discrimination—the Santa Fe meeting is often credited with launching the field.

The meeting, the papers of which are collected in the first volume in this series (Anderson, Arrow & Pines, 1987), was convened to explore whether ideas and methods from complexity science might contribute to economics. The meeting was vividly described by popular science writer Mitchel Waldrop (1992) as a clash of intellectual titans. Participants included a clutch of Nobel laureates such as the physicists Murray Gell-Mann and David Pines, and economists Kenneth Arrow and (later laureate) Thomas Sargent, complexity theory pioneers W. Brian Arthur, Stuart

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Kauffman, and John Holland, and (then) young up and coming economist Lawrence (Larry) Summers and physicist J. Doyne Farmer. While the meeting did not produce anything like a consensus, it raised a set of fundamental questions about the nature of the economy and launched a program of research at SFI. Catalyzed by that program, an interdisciplinary community of scholars formed and coalesced around a body of work that Brian Arthur would later label "complexity economics."[‡] (See Ch. 1 for a definition of complexity economics. Papers and accounts of subsequent SFI economics meetings can be found in Arthur, Durlauf & Lane, 1997; Blume & Durlauf, 2005; and Arthur, Beinhocker & Stanger, 2019.).

Some three and a half decades later that community has grown, become global, and its work has started to have important impacts on topics ranging from financial crises to economic development, climate change, labor markets, supply chains, and macroeconomics (e.g., Iori and Hommes, 2015; Farmer 2024; Axtell and Farmer, 2025; Bednar, et. al. 2025).

During this same period, economics changed significantly. The field is no longer dominated by the largely fact-free body of neoclassical theory that the Santa Fe Institute scientists criticized in 1987. Economics has taken a major turn towards empirical work, has embraced behavioral economics, rediscovered the importance of institutions, recognized the failures of standard (DSGE) macroeconomic models, and expanded its methodological toolbox to include structural models, Heterogeneous Agent New Keynesian (HANK) models, principal-agent models, microsimulation, and field experiments. It has also taken a more rounded and realistic view of markets; increasingly incorporating information asymmetries, frictions, externalities, endogenous preferences, power relations, cultural norms, identity, and various forms of market failure into its theories and models.

But as economists have been attempting to grapple with the messy complexity of the real-world economy, they have increasingly been running into the limits of historical tools and methods. In particular, analytical models typically require simplifications (such as utility maximizing agents) to produce closed-form solutions. The complex systems community, meanwhile, has significantly advanced the development of tools and methods that can model such complex economic phenomena in highly realistic and empirically validated ways. These methods, which include statistical physics models, network models, agent-based models, and machine learning and other forms of AI models, have ridden the wave of advances in computation and data, providing researchers with powerful tools the scholars at the 1987 meeting could have only dreamed of.

[‡] The first printed use of the term "complexity economics" is in Arthur (1999). However, Arthur began using the term in lectures as early as 1994.

This chapter will argue that bringing such complex systems ideas and methods into the theoretical and methodological heart of economics has the potential not just to advance the field and deliver new insights, but to reshape the economic paradigm much more broadly.

Economic paradigms play a role in society that is different than physical science paradigms. Like physical science paradigms, economic paradigms attempt to explain phenomena with empirically supported theories and models. But unlike physical science paradigms, economic paradigms also provide guidance as to how the system could and *should* work according to some set of normative criteria. This normative function means that economic paradigms themselves influence the behavior of the system through policy, politics, business, the law, and the broader culture.

The 20th century was dominated by three major economic paradigms: Marxist socialism, Keynesian social democracy, and what we will refer to as the neoliberal consensus. This chapter will argue that all three of these historical paradigms failed in the face of various crises, losing both intellectual credibility and popular support. Most recently, support for the neoliberal consensus, which dominated policy and politics in the U.S. and much of the West from the 1970s, collapsed in the wake of the 2008 global financial crisis. This created a paradigm vacuum into which populist, authoritarian, politicians have stepped in many countries around the world, threatening not just their domestic economies and democracies, but causing breakdowns in the international order.

Various groups in academia, as well as in civil society, and business, have been calling for a new economic paradigm that can address the failures of the neoliberal consensus, provide a compelling alternative to the populists, and restore trust in liberal democracy (see for example Naidu, Rodrik & Zucman, 2019, Boushey 2019, Wong 2022). Our concern, and a central thesis of this chapter, is that while economic issues are not the only issues that underpin support for authoritarian populists, the problems created by neoliberal policies created fertile ground for that support. Without alternative economic explanatory frames, policies, and political narratives, those who wish to uphold liberal democracy—both conservatives and progressives—will struggle to regain support from the authoritarian populists. A new paradigm is needed both to address the failures of the 20th century paradigms (e.g., inequality, financial crises, "left behind" communities), but also to address urgent 21st century challenges, such as climate change and the impact of technologies such as artificial intelligence.

Important progress has been made on this agenda, with contributions from economists, political scientists, sociologists, historians, philosophers, policy experts,

legal scholars, and many others; but this broad, ambitious project remains incomplete. This chapter will endeavor to make three contributions:

1.) Define more specifically what constitutes an economic paradigm and use that framework—what we call an "ontological stack"—to identify why the neoliberal consensus failed.
2.) Argue that a new paradigm is indeed emerging, but there are critical gaps in the scientific explanatory layers of that paradigm that complexity economics can help fill.
3.) Outline an agenda for more closely integrating complexity economics into economics and the cross-disciplinary project of paradigm construction.

We conclude that by integrating complexity economics into the broad structure of a new paradigm, there is potential for new answers to some of our greatest challenges, and perhaps even a healthier politics that can help heal some of our deepest divisions.

2. Paradigm Change in Economics

The most well-known use of the term "paradigm" comes from Thomas Kuhn's (1962) landmark work, where he describes the progress of science not as a steady accumulation of knowledge, but instead as episodic, following distinct phases: "Normal science" where researchers solve puzzles within an established, communally shared framework; "crisis" where anomalies, inconsistencies, and falsifications of the established framework accumulate; and "paradigm shift" where a new framework emerges that both better explains the anomalies and incorporates the successes of the previous framework. This shift is then complete when it is adopted by the community and becomes the new framework for "normal science".

While Kuhn's theory is recognized as a simplification of the messy human endeavor of science, and glosses over important epistemological, methodological, and cultural differences across scientific fields, it is nonetheless a useful way to think about the broad historical pattern of scientific advance. Historians of economic thought likewise tend to take an episodic view of the development of economics, identifying distinct historical eras such as classical economics, the marginalist revolution, and neoclassical synthesis (e.g., Ekelund and Hébert, 2013).

All sciences have both an explanatory and applied role, for example the relationships between physics and engineering, or between biology and medicine. So too does economics in its relationship with business, finance, law, and public policy. However, there is a fundamental difference between economics and the physical sciences. While changes in physical science paradigms often have major

impacts on the world through their application, which particular paradigm is held by scientists *does not affect or change the fundamental laws or behaviors of the system itself*. Whether physicists believe in Newtonian mechanics or Einsteinian relativity does not affect or change the laws of gravity. Nor does whether biologists accept Darwinian or Lamarckian theories of evolution affect how species evolve. Physical scientists observe, model, and theorize about natural laws and regularities that operate independently of human action.[§]

Social systems such as economies, in contrast, are created by human action. The "physics" of such systems, or "rules of the game," are products of human thought. The order in such systems emerges from what humans believe and think and how they behave. Such human-created orders are constrained and shaped by physical and biological laws—we can't make products that violate the laws of physics, and human behaviors are strongly influenced by biology and our evolutionary history—but the emergent behaviors of social systems are largely shaped by human-created norms, beliefs, customs, knowledge, institutions, and technologies.

This creates a reflexive feedback loop between our beliefs about the system and how the system behaves (Soros 2013, Beinhocker 2013). Throughout history, humans have tried to understand and explain their social systems (positive theories) and then used that understanding to devise views (normative theories) as to how the system *should* work, whether for the betterment of society or for the betterment of themselves or their group. People furthermore use that understanding to construct narratives to convince others of the rightness of their views, and then individuals and groups take actions based on those views that change the behavior of the system. Again, this is a distinctive feature of social science theories. Physicists do not have a theory of how the universe *should* work, nor do their theories influence how it *does* work.

For most of history, these reflexive feedback loops between beliefs and system behavior were based on religious, philosophical, and political views. For example, a society's religious beliefs and cultural norms might strongly influence how individuals behave and how its institutions are organized, both of which would influence how its economic system performed. The performance of the economic system in turn would influence the evolution of beliefs and norms over time in a reflexive loop.

[§] One might question whether the measurement problem in physics is an exception. But this too is a general physical law independent of human thought or belief. Any interaction with the outside world in a way that records or distinguishes one probabilistic outcome from another causes the collapse of a quantum wave function into a single state, not just a human observer. It occurs regardless of our views on the theories of Werner Heisenberg and Niels Bohr.

As economics began to develop as a field in the 18th and 19th centuries, it also began to play a reflexive role in not just describing *how* the economic system works but shaping how it *does* work. For example, Adam Smith's arguments against the mercantilist system of his time and advocacy of free trade were influential in the 1846 repeal of the Corn Laws in Britain and Prime Minister Robert Peel's pro-trade policies. Likewise, David Ricardo's theories had important impacts on the taxation, trade, and monetary policies of that era.

Perhaps the most dramatic illustration of this reflexive feedback loop between economic ideas and economic reality was the influence of Karl Marx and Friedrich Engels. In the 20th century their theories of socialism provided the intellectual inspiration for revolutions around the world that led to radical experiments in running economies on communist principles. Those experiments resulted in disaster (e.g., it is estimated that the collectivization of agriculture led to 5 to 8 million deaths from starvation in the Soviet Union and 15 to 45 million deaths in China) and those failures in turn fed back into economic theory, stimulating critiques of central planning and helping motivate the rise of the neoliberal free market ideology in the West (Burgin 2012).

This reflexive interplay between positive and normative economics means we need to take a broader view of what is meant by a "paradigm" than is typically applied in the natural sciences. We must think of a paradigm in an economic context as not just a set of explanatory theories, models, and methodologies, but as a broad set of interlocking ideas that also includes moral values, normative analysis, policies, and political and public narratives.

3. The Ontological Stack

With both these positive, normative, and reflexive roles of economics in mind, we can now more carefully define what constitutes a paradigm in economics. Beinhocker (2020) introduces the concept of an *ontological stack*—a set of mutually reinforcing, interlocking concepts that form the basis of an economic paradigm. Bowles and Carlin (2021) introduce a related framework for decomposing economic paradigms in their analysis of the challenges faced by modern capitalism and their call for a new paradigm. Building on and combining these two frameworks, we propose a revised ontological stack that explicates the levels and elements of an economic paradigm (Table 1):[**]

[**] This framework also draws on Beinhocker's work with Nick Hanauer in their forthcoming book, *Market Humanism*. Note that Bowles and Carlin (2021) use the term "paradigm" in two senses: The first in the Kuhnian sense referring to a scholarly discipline, while the second is a "policy paradigm". We have combined the two meanings in our ontological stack framework due to the reflexive interplay between the two.

Table 1. The "ontological stack" of an economic paradigm

Functional levels	Layers of theory & practice	Explanation
Values	Moral foundations	Moral values and philosophical traditions that define "good" and "bad" in the system
Scientific	Behavioral theory	Theories of human motivations and decision making
	Economic systems theory	Theories of agent interactions and collective economic behavior
	Processes of change	Theories of how the economic system changes over time
Normative	Normative analysis	How we evaluate relative performance or change in the system
	Metrics	How we measure economic performance and change
	Political economy & ideology	How we should organize the economy & society to maximize performance
	Emblematic policies	Key policies that would make the system perform better
	Public and political narratives	Stories that explain how the system works and how it could perform better

At the highest level an economic paradigm has three "functional levels": 1.) A set of values that define what is "good" and "bad" in the system, 2.) a set of scientific theories and models that explain how the system works, and 3.) a set of normative functions that connect the values and explanations to derive actions and changes that would make the system "better" or "worse".

These three functional levels are in turn composed of multiple layers of theory and practice: The values are built on moral foundations from philosophy, religious traditions, and cultural norms. The scientific explanations include theories of human behavior, of economics systems, and of processes of change. And the normative layers include frameworks for normative analyses of change in the system (i.e., will this change make things better?), metrics for measuring system performance, political economy and ideological theories as to how the system should be organized, emblematic policies (a term borrowed from Bowles & Carlin, 2021) that exemplify the values, explanations, and normative frameworks in action, and narratives to explain the paradigm and justify its political and policy implications to the public.

We refer to such a collection of inter-related ideas as an "ontological stack" because they provide a systematic vocabulary and structure for how people think about entities and relationships in the economic domain and are used for organizing knowledge and framing debates.[††]

[††] Our use of the term "stack" is analogous to and inspired by how the term is used in software engineering; a bundle of technologies used to build and run an application, where each "layer" handles a function for part of the system (e.g., operating system, server, database, user front end, etc.). Similarly, in the ontological stack, the ideological, policy, and narrative "front-ends" sit atop deeper layers of ideas.

The easiest way to see how such an ontological stack works, and how the different levels inter-relate and support each other, is to illustrate it with an example. Table 2 provides the ontological stack for what we refer to as the *neoliberal consensus*. This paradigm is a constellation of ideas on the workings and performance of market economies. These ideas have intellectual roots in the 18th and 19th centuries that were then mathematically formalized during the 20th century. Those ideas rose to political prominence in the U.S., UK, and many other countries, as well as international institutions, helping shape the global economic order from the 1970s into the 2010s, playing a reflexive organizing role in the economy and society.

This paradigm is often popularly referred to simply as "neoliberalism", but we feel it is more accurate to call it the *neoliberal consensus* because it is in fact a fusion of multiple intellectual strands, including 18th century utilitarianism, 19th century marginalist economics, 20th century neoclassical theory, and 20th century neoliberal political economy and ideology, along with influences from libertarian philosophy. These strands came together powerfully in the latter half of the 20th century to form a broad consensus in the political, policy, business, finance, and legal communities on the workings and organization of free market economic systems (sometimes also referred to as the "Washington consensus" or "Davos consensus").

Table 2. The ontological stack of the neoliberal consensus paradigm

Layer in the ontological stack	Neoliberal consensus	Example figures
Moral foundations	Hedonism, utilitarianism, individual rights, liberty	Epicurus, Hobbes, Bentham, Nozick
Behavioral theory	Self-interest, utility max, rational actor, methodological individualism	Jevons, Marshall, Robbins
Economic systems theory	General equilibrium, neoclassical	Walras, Samuelson, Arrow, Hicks
Processes of change	Exogenous forces and shocks, competitive pressure, incentives	Solow, Ramsey, Cass, Koopmans, Hayek
Normative analysis	Welfare economics	Pareto, Pigou, Kaldor
Metrics	GDP, productivity, return on capital	Kuznets, Stone, Meade
Political economy & ideology	Neoliberalism; markets efficient, gov't only for limited "market failures"	Friedman, Hayek, Buchanan
Emblematic policies	Tax cuts, deregulation, free trade, shareholder value maximization	Feldstein, Stigler, Becker, Ohlin, Friedman
Public and political narratives	Trickle-down, small government, growth, freedom	Ronald Reagan, Bill Clinton, Margaret Thatcher, Tony Blair

This ontological stack was then used to justify major structural changes in Western economies in the late 20th and early 21st centuries, including privatization, deregulation, the globalization of capital markets, free trade agreements, shifts in tax policy, a reduction in union power, a laissez-faire approach to technological change, a reduction in anti-trust action, and shifts in corporate governance practices to prioritizing shareholders over other stakeholders. While the political version of this

paradigm is often associated with conservative figures such as Ronald Reagan and Margaret Thatcher, there was also a center-left version represented by figures such as Bill Clinton and Tony Blair.

In Table 2 one can see how each level built on and reinforced the others. Utilitarian philosophy provided a foundation for utility theory and the rational actor behavioral model. The utility maximizing rational actor model was in turn essential in enabling the mathematics of general equilibrium theory to develop. That model then yielded welfare theorems (rooted in utilitarian ethics) that supported normative neoclassical views on institutions and policies. Those neoclassical views were often congruent with neoliberal ideas on political economy, which in turn were used to support free market policies, political agendas, and public narratives.

It is important to note that while the ideas in the paradigm inter-relate and broadly cohere, this does *not* mean there were not disagreements and inconsistencies within it. For example, we have placed both Paul Samuelson and Milton Friedman within this paradigm, even though they often disagreed (most publicly in their respective *Newsweek* columns), particularly on issues of policy. Samuelson, for example, supported an active role for government in addressing various market failures while Friedman advocated a minimalist role for the state. But their arguments were occurring *within* the same broad ontological framework—such disagreements are what Kuhn would have called "normal science". They shared many values, assumptions, and theories from deeper levels of the ontological stack—for example, assumptions about human behavior and theories about the basic workings of markets—but they differed on many details of economic theory or whether specific issues constituted market failures requiring government intervention or not.

There were also debates across levels of the stack. For example, Austrian political economy theorists such as Friedrich Hayek were vocal critics of neoclassical economic theory. But Hayek and neoclassical economists such as Thomas Sargent also had much in common, such as their critique of Keynesianism, skepticism of government intervention, respect for market mechanisms, and shared values around individual freedom. Likewise, at the political level of the stack, there were important policy disagreements between figures such as Ronald Reagan and Bill Clinton, but they and their respective technocratic advisers were arguing within a shared economic framework with much they agreed on (e.g., the benefits of free trade).

While the neoliberal consensus is a big tent, it is also distinct from other identifiable paradigms. One could, in principle, create an ontological stack for the Marxist socialist paradigm. Such a stack might include moral foundations rooted in egalitarianism, behavioral theories based on class identity, economic systems theories that included the labor theory of value, processes of change based on historicism, and political economy implications for worker ownership of the means

of production, and so on. And again, while there are varieties of Marxist thought, and many disagreements amongst Marxists, their debates are within a common paradigmatic framework; their worldview is shaped and defined by the stack.

Similarly, one could create a distinct paradigm stack for Keynesian social democracy, with values of social justice at its base, extending through Keynes's General Theory, and into normative implications and policies for counter-cyclical spending, the welfare state, and full employment. Keynesian social democracy is also a big tent encompassing strands from leftist Fabians to centrist social democrats, to more market oriented *ordoliberals* in Germany. Keynesianism also illustrates how paradigms cross and interconnect. For example, Paul Samuelson made fundamental contributions to neoclassical economics and thus we have cited him in Table 2, but he was also an important advocate of Keynesianism (not least through his highly influential textbook).

Looking at other systems of economic thought, one could also say that China's state-led capitalist economy that evolved following Deng Xiaoping's reforms in the 1970s and 80s is yet another paradigmatic model, which draws on China's own intellectual and political history as well as elements from each of the three paradigms above. Finally, the "America First" economic nationalism promoted by Donald Trump and his supporters could arguably be seen as still another distinct paradigm (although arguably less developed and coherent than the examples above), with roots in historical right-wing nativist and populist traditions, and drawing some elements from the neoliberal consensus (e.g., tax cuts) and other elements from older modes of thinking (e.g., trade tariffs and mercantilism).

4. Evaluating Economic Paradigms

This leads to an important point: not all paradigms are created equal. Some are better than others. But what constitutes "better"? How should we evaluate an economic paradigm? Paradigms in the natural sciences are typically evaluated based on their explanatory and predictive powers, supported by empirical tests (Popper 1959, Kuhn 1962). However, the positive, normative, and reflexive nature of economic paradigms require us to think differently about how to evaluate them.

Table 3. Evaluating an economic paradigm

Functional Levels - Evaluation criteria	Layers in the ontological stack
Values – Broadly accepted and ethically defensible	Moral foundations
Scientific – Rigorous, explanatory theories and models making empirically testable predictions; falsifiable	Behavioral theory
	Economic systems theory
	Processes of change
Normative – The impact of recommended behaviors, policies, and institutional structures on system performance and individual outcomes as evaluated by the values	Normative analysis
	Metrics
	Political economy & ideology
	Emblematic policies
	Public and political narratives

Table 3 presents a proposal noting that different functional levels of the ontological stack require evaluation by different criteria. The first layer in the stack is a set of moral values and for which there isn't an objectively "right" or "wrong" answer. Instead, we can ask whether the values are broadly accepted in society and whether they are ethically defensible (i.e., do they hold up to scrutiny and are consistent with basic ethical principles)? The former test is necessary because a system that is not based on broadly shared values will not be seen as legitimate. The latter test is necessary as history shows it is possible for societies to have broadly shared values that are morally indefensible (e.g., support for slavery).

There are then three layers of the ontological stack that are comprised of positive explanatory theories—a behavioral theory, economic systems theory, and theory of economic change. These can and should be evaluated from a scientific standpoint and subject to Popperian falsification tests (Popper, 1959). Have the theories been rigorously defined and articulated (often by means of mathematical or computational formalization)? Are they logically coherent and mutually consistent? Do they make testable, falsifiable predictions? What have the results of those empirical tests been?

The next five layers then provide the normative end of the stack: how do we analyze whether a change will result in "good" or "better" economic outcomes, how do we measure it, how do we organize the system to deliver "good" or "better" outcomes, what are the specific policies, and how do we explain and build support for such changes? These normative elements should be evaluated on their performance in the world: have the recommended behaviors, policies, and institutions had a positive impact on human wellbeing? Have they delivered the "good" or "better" outcomes (consistent with the moral values) that they promised? Have there been negative consequences or side effects? What have the trade-offs been?

5. The Failed Paradigms of the 20th Century

Three of the paradigms described above dominated the 20th century: Marxist socialism, Keynesian social democracy, and the neoliberal consensus. But by the early 21st century all three had failed. All three faced crises, lost their intellectual credibility, and lost popular support.

Marxist socialism hit its high-water mark in the 1970s when it was the governing ideology for about 1.5 billion people—nearly a third of the world's population. While some might point to claimed successes in industrialization, healthcare, rights for women, and other social conditions, the overall historical economic record was calamitous. Deprivation, shortages, inefficiencies, corruption, and political oppression were endemic in Marxist socialist economies around the world. From the 1970s onwards, populations rejected these economies and political systems, whether through migration, revolution, or reform. This culminated in *glasnost* in the USSR, the collapse of the Berlin Wall, and Deng Xiaoping's "Reform and Opening Up" in China. By the 1990s Marxist socialism had lost its grip on countries around the world.

Meanwhile, Keynesian social democracy dominated the economic discourse and politics of the most economically powerful nations of the world, from New Deal America in the 1930s, through Western European and Japanese postwar reconstruction in the 1940s-60s. During this period, the paradigm delivered increasingly inclusive growth, social protections, and rapidly rising living standards across broad populations. There is debate as to how much of this success was attributable to the unique conditions of postwar reconstruction versus the policies pursued. Yet, from the 1970s the paradigm was seen as failing in the face of high inflation, unsustainable expansion of the social welfare state, and a loss of economic dynamism. With the collapse of the Bretton Woods system, oil shocks, stagflation, labor unrest, government debt crises, and painful recessions, by the 1980s, Keynesian social democracy was subject both to intense intellectual criticism and had lost much of its political and electoral support.

As support for Marxism and Keynesianism faded, the neoliberal consensus appeared to be the last paradigm standing and took hold of the economic and political agendas of many Western countries in the 1980s and 1990s and guided international institutions such as the IMF, World Bank, and WTO, thus inspiring Williamson's (1989) label, "The Washington Consensus". Through the 1990s the paradigm was viewed as a success; many countries pursuing these policies enjoyed a "goldilocks" period of high growth, low inflation, and low interest rates, and as global markets opened and technology innovation accelerated.

However, these perceived successes hid darker multi-decade trends in wage stagnation, declining social mobility, expanding income and wealth inequality, greater economic insecurity, and the capture of most of the gains of growth by the wealthiest members of society (Nolan 2018). The neoliberal consensus faced its own crisis in 2008. The global financial collapse not only caused misery around the world but also cracked confidence that the neoliberal politicians and technocrats knew what they were doing. This loss of confidence, along with long simmering tensions over other issues (e.g., immigration, race, gender, culture), created an ideological vacuum into which stepped opportunistic authoritarian populists in countries around the world.

But arguably the most consequential failure of the three 20th century paradigms has been climate change. While the economic record of the three paradigms has differed considerably, all three oversaw periods of massive industrialization and exponentially increasing energy use, emissions, and waste production, leading to the global environmental crisis we face today. To be truly successful, an economic system must deliver the twin goals of high standards of living for people *and* operate within planetary biophysical boundaries (Raworth, 2017; Beinhocker, 2023). But research shows that *no* current economic paradigm in operation in the world today delivers on these twin goals of high standards of living *and* sustainability (O'Neill, et. al. 2018).

These failures in real-world performance (albeit to varying degrees) then lead one to ask, why? While it is beyond the scope of this chapter to delve deeply into the ontological stacks of each paradigm and provide a critique, we can surmise that something went wrong in the transmission between each paradigm's professed values—many of which were both widely accepted and defensible (e.g., Marxist socialism's promotion of egalitarian values, Keynesian social democracy's championing of social justice, and the neoliberal consensus's advocacy for individual rights, freedom, and meritocracy)—through the scientific layers, and into practical applications in the real world. None of the three dominant 20th century paradigms succeeded in creating the worlds they promised.

While it is too high a standard to expect any paradigm to deliver utopia, we should, however, expect the scientific layers of a paradigm to help us at least steer towards "better" (Popper, 1945). But if one's causal explanations of how the economy works is not correct—if it is not rigorously articulated, modeled, falsifiable, and empirically tested—then attempts to translate values—no matter how meritorious—into "good" or "better" real world outcomes via policies and institutions, will inevitably go awry. Instead of creating a more equal society, collectivizing agriculture killed millions. Instead of helping the poorest succeed, the welfare state created dependency. Instead of creating trickle-down growth, tax cuts for the rich enabled plutocracy.

And instead of creating prosperity for future generations, all three paradigms have endangered the future of life on Earth.

But history shows that from paradigm failure, new paradigms emerge. Marx and Engels presented their ideas as a theoretical counter to classical economics and as an alternative to the injustices of 19th century laissez-faire capitalism; Keynes was attempting to offer an alternative to both laissez-faire capitalism and revolutionary socialism; and the neoliberals emerged in response to Cold War threats from communism and the perceived failures of Keynesianism.

So, the question is, can a new paradigm be created with scientific layers that better explain economic reality? A paradigm that connects strong moral foundations to better outcomes? And what contribution to such a program could complexity economics make?

6. Building a New Paradigm and the Role of Complexity Economics

Motivated by the collapse of the neoliberal consensus and alarmed by the rise of authoritarian nationalist populism, since the 2010s, multiple groups of scholars have been engaged in work to develop an alternative paradigm. Examples include the Emerging Political Economies Network (of which SFI is a member), the Institute for New Economic Thinking (INET), Economics for Inclusive Prosperity (EfIP), the London Consensus initiative, and a growing number of research centers, think tanks, NGOs, and funders.

Drawing on our framework, we would observe that much of the energy in these efforts has been focused on the bottom and upper layers of the ontological stack. There has, for example, been productive debate and work on the moral foundations of the economy (e.g., Bowles, 2016, Collier and Kay 2020, Sandel 2020). Potential contributions to alternative moral foundations come from a variety of figures and philosophical traditions; for example, Amartya Sen (1999) and Martha Nussbaum's (2011) work on capabilities, Elizabeth Anderson's work on inequality (1999), Danielle Allen's (2017) writing on power and justice, Alasdair MacIntyre's virtue ethics (1999), and Daniel Chandler's (2024) modern interpretations of Rawls. There has also been promising work on new frameworks for normative analysis (e.g., Beinhocker, et. al. 2023), political economy (e.g., Levi & Farrell 2023; Naidu, Rodrik & Zucman, 2019, Besley 2023), and policies (e.g., Rodrik, 2025, Besley, Bucelli & Velasco 2025).

There has also been progress on the scientific layers stemming from the significant changes in economics discussed in the Introduction. There have also been important

efforts to synthesize this progress, most notably in the CORE project (core-econ.org), a global effort by over 30 authors to create a modern introductory text that is substantively different from previous standard texts (Bowles & Carlin, 2020).

Yet, despite this progress, significant gaps remain. The reason, we believe, is economics is increasingly running into the limits of its historical and current methodological toolkit. Economists are asking the right questions. For example: How do we incorporate greater behavioral realism into our models? How do we model profoundly disequilibrium events like financial crises or climate change? And, how can we better understand structural changes, such as those driven by technology? But the field has not necessarily had the right tools, methodologies, and conceptual frames to answer them.

This is where the complex systems community can contribute. Specifically, there are eight types of problems where complexity economics has a track record of employing methodologies that provide empirically supported insights that are differentiated from more conventional methods. This volume has a number of examples illustrating work on these issues, but below we have provided additional examples from the literature:

1. **Behavioral realism** – While utility maximization may be a reasonable simplification for some types of problems, greater agent behavioral realism is essential for others. Modern behavioral science portrays humans as often pursuing multiple goals, making decisions employing a variety of heuristics, engaging in heuristic switching, and learning and adapting (Gigerenzer & Selten, 2001). While such behavioral richness may be impossible to collapse into a single utility function, it can be represented computationally in agent-based simulations. For example, Hommes (2013) estimates the heuristics used by subjects in asset pricing decisions in laboratory experiments and then simulates heterogeneous agents employing those heuristics and engaging in heuristic switching learning behavior in an empirically validated agent-based model. The model shows how financial instabilities can be created through the dynamic interactions of ecologies of heuristics, an insight that cannot be generated by models with homogeneous, utility maximizing agents.

2. **Institutional realism** – Analytical models are often highly limited in the institutional detail they can portray. Yet, those details can be critical to explaining the phenomena of concern. For example, standard models of financial markets assume random arrivals of buy and sell orders and that markets automatically and instantaneously clear those orders. These assumptions then underpin analyses showing market efficiency. Yet, Fabrizio Lillo and J. Doyne Farmer (2004) showed empirically that order flows are not random and obey a long-memory process. Lillo, Szabolcs Mike, and Farmer

(2005) then hypothesized that this long-memory in order flows was due to a set of institutional details in real world markets, specifically delays in market clearing, the common practice of traders splitting large orders and executing them incrementally, and the distribution of investor sizes (from Warren Buffets size investors to individuals with small retirement accounts). Using methods from statistical physics, the authors built a stochastic process model of the market microstructure which they then simulated and used to make quantitative macroscopic predictions about order flows. Those predictions were then empirically validated 18 years later by Sato and Kanazawa (2023) who were able to obtain a previously unavailable, detailed 9-year data set from the Japanese stock market. Further work by Farmer and colleagues (2013) showed how order splitting behaviors interact with the structure of limit order books to impact prices and market efficiency, with implications for market design and regulation.

3. **Market disequilibrium** – Economists use the term "equilibrium" in two ways: First is in the sense of market clearing where supply equals demand and a price is discovered. The second is in game theory where agents understand the strategy space and have reached a point where their strategies are no longer changing. The first sense is often not a bad assumption in real world markets, particularly over longer time scales. But even so, there are situations, such as financial crises, depressions, or other major economic dislocations, where markets can remain out of equilibrium for extended periods of time. Or situations (per above) where behavioral and institutional factors cause markets to deviate from equilibrium. Conventional models typically have little to say about such situations; as the most widely used graduate text (Mas-Colell, Whinston & Green, 1995, p. 620) puts it, "Economists are good (or so we hope) at recognizing a state of equilibrium but are poor at predicting precisely how an economy in disequilibrium will evolve." Agent-based models (ABMs) provide a means for simulating the evolution of such systems out of equilibrium. Kirman and Vriend (2001), for example, provide an empirically informed microeconomic example in their study of the Marseille fish market (which also includes behavioral and institutional realism), while Poledna, et. al. (2023) provides a macroeconomic example which compares out of sample forecasts of their ABM with standard DSGE models.

4. **Strategy disequilibrium** - The second type of equilibrium/disequilibrium in economics, the non-convergence of games in a strategy space, is also amenable to study using complex systems methods. In a result of highly general importance, Pangallo, Heinrich & Farmer (2019) show that in a computationally large space of possible games, that games where strategies converge to equilibrium is exceedingly rare. In games with more than a few

players, and with strategies that include learning (derived from experiments with human players), the games generate endogenous oscillations in best-reply cycles that don't converge. Most games in the real-world economy involve more than a handful of players and feature heterogeneous strategies with learning and adaptation, in which case as the authors put it (p.1), "equilibrium is typically an unrealistic assumption." Drawing on techniques from biology, complexity researchers model strategy spaces as dynamic ecologies, showing for example how this can lead to market malfunction (e.g., Scholl, Calinescu & Farmer, 2020).

5. **Networks** – Economies are comprised of various kinds of networks, from supply chains to financial networks, labor market networks, and so on and their influence on economic phenomena has been of growing interest to economists (e.g., Jackson 2014, Carvalho 2014). Cross-disciplinary studies of networks have been a core subject of complexity economics since its earliest days. Pichler, et. al. (2020) introduced a dynamic input-output model with micro detail on the UK supply chain and occupations that was used to make real-time forecasts of the economic impacts of the COVID-19 pandemic. Later analysis (Pichler, et. al. 2022) found that the forecasts produced by that model were significantly more accurate than those provided by standard, aggregate macroeconomic models, such as those used by the Bank of England.

6. **Emergence** – Complexity theorists view the economy as a system where macro behaviors emerge bottom-up from lower-level heterogeneous micro and meso-level behaviors and structures, and emergent patterns and structures can exhibit collective behaviors (and in biological and social systems, agency) that is distinct from lower-level units. Philosophically, this stance bridges the long-standing debate in social science between methodological individualism (e.g, Weber, Schumpeter, Elster) versus methodological holism (e.g., Durkheim, Marx). Practically, instead of assumptions of representative agents linearly adding up to generate macro phenomena as in most standard macroeconomic models, ABMs explicitly model heterogeneous micro and meso-level behaviors and structures and the macro phenomena emerge bottom-up. For example. Asano, et. al. (2021) develops a macroeconomic model that loosens the representative, rational agent constraint and models the dynamics of myopic heterogeneous households in a social network. The model generates emergent macro business cycles and inequality consistent with stylized facts and demonstrates critical transition points in system behavior that could be relevant to policymaking.

7. **Evolution –** Economics has had a long tradition of evolutionary theorizing and modeling (e.g., Nelson & Winter, 1982); however, it has historically sat

outside of the mainstream of the field (it is interesting that no Nobel has yet been awarded for evolutionary economics). There are two senses in which evolution is central to a complex systems view of the economy (Wilson & Kirman, 2016): First, is that humans themselves are products of evolution and this has influenced important aspects of both our individual and social behavior, notably how multi-level selection has shaped humans to be prosocial and highly cooperative (Bowles & Gintis, 2011; Wilson, et. al. 2023), which is an essential fact in explaining the large-scale, cooperative order creation amongst non-kin that characterizes the economy (and is counter to traditional assumptions of individual, self-regarding rationality). Second, is that human social systems themselves evolve according to generalized Darwinian principles (Hodgson & Knudsen, 2010; Beinhocker, 2011); including, human culture broadly (Henrich, 2016), technology (Arthur, 2009; Ch. 2), and institutions (Hodgson, 2004; Nelson, 2005). Advances have also been made in formalizing evolutionary perspectives in economics. Peyton Young (1993, 1998) utilizes evolutionary game theory to model how stable social norms and structures can evolve through evolutionary processes. Herbert Gintis (2017) provides both a unifying theoretical perspective and formal models using evolutionary game theory and Markov processes to explore evolutionary interactions between individual and collective system behaviors. Dosi, et. al. (2017) use ABM to bring an evolutionary perspective into macroeconomics, integrating Schumpetarian technology dynamics with a Keynesian model of demand fluctuations and examining implications for policy.

8. **Environment** – The standard approach to integrating environmental concerns into economics has been to treat the environment as an externality—an infinite source of resources and infinite sink for waste, outside the bounds of the economy itself. This perspective has anchored much of the research in models of market failure, Pigovian taxes, shadow prices, cost-benefit analysis, etc. But this perspective fails to capture the two-way dynamics of interactions between the environment and economy, as well as the non-marginal, structural transformations required to create an economy that operates within biophysical limits compatible with life flourishing on Earth (Beinhocker, 2023). The complex systems perspective, however, sees the economy as an open thermodynamic system, embedded in the physical environment, with flows of energy, materials, and information inputs leading to order creation and entropy reduction within the system, and the exporting of higher entropy waste heat, gases, and materials back into the physical environment—the "metabolism of civilization" as Farmer (2024, pp. 48-72.) puts it. This entropic perspective has been core to the development of ecological economics (Georgescu-Roegen, 1971; Daly, 1977), but like the evolutionary perspective, has sat outside the mainstream. But if economics is to fully grapple with the

profound issues of climate change, ecosystem destruction, and their implications for the economy, policy, and society, it must move beyond its narrow frame of market failure. Researchers have shown that the economy as metabolism is not just a metaphor but can be studied and modeled empirically (Schandl, et. al. 2024) with implications for how equitable and high living standards can be achieved within biophysical boundaries (O'Neill, et. al. 2018). One of those implications is deep structural changes in our technologies and institutions. Way, et. al. (2022) provides an empirically grounded model showing how a dynamic view of technology change upends standard (e.g., Nordhaus, 2017) cost-benefit analyses and concludes that a rapid transition to net-zero energy technologies yields significant economic benefits, even absent the benefits of avoided climate damage.

If we step back and look across this list—behavioral realism, institutional realism, market and strategic disequilibrium, networks, emergence, evolution, and environment—what we see is an opportunity to make economics more capable of scientifically capturing the complexity of economic phenomena, and more relevant to addressing complex real-world challenges.

These eight points capture much of the agenda of modern economics, where cutting-edge work is both needed and is being done. This volume and the literature cited, shows that the inter-disciplinary complex systems community can now claim to have a multi-decade record of using tools, methods, and perspectives that are differentiated from those historically used in economics, to generate new, empirically validated, insights.

Mapping back to our framework of economic paradigms (Table 4), we can see how the complex systems community is making crucial contributions to what we have called the three scientific layers of the ontological stack:

Behavioral theory – Incorporating a cross-disciplinary perspective on real human behavior, including heuristic decision making and learning, prosociality and cooperation, multiple goals, social norms, and culture, into economic models.

Systems theory – A systems theory rooted in the idea of the economy as a complex adaptive system of networks within networks, that exhibits both equilibrium and disequilibrium behaviors, where macro patterns emerge from dynamic interactions at the micro and meso levels, and that is intertwined with the physical environment.

Processes of change – Where much change is endogenous, evolutionary, and multi-level, with the evolution and co-evolution of technologies and institutions (within the broader evolution of human culture) driving the long-term self-creation,

unfolding, and development of the system—or, borrowing a term from evolutionary biology, what Brian Arthur has referred to as economic "autopoiesis"[⌗⌗].

Putting these pieces together with the other layers in the broader project of new paradigm construction, we can begin to see a sketch of what such a new paradigm might look like (Table 6):

Table 4. An emerging new paradigm

Level in the ontological stack	A new 21st century paradigm	Comments
Moral foundations	Alternatives to Benthamite utilitarianism	E.g., capabilities; moral & democratic equality; virtue; communities of fate; modern interpretations of Rawls
Behavioral theory	Modern behavioral science with a cross-disciplinary perspective	E.g., costly cognition, heuristic decision-making, adaptive learning, multi-motivated, prosociality, role of norms, culture, and identity, social nature of knowledge
Economic systems theory	Complex adaptive systems	Diverse agents, networks, nonlinearities, dynamics, multi-level, emergent, non-ergodic, embedded, open
Processes of change	Endogenous, evolutionary	Universal Darwinism, multi-level and multi-domain evolution (biology, culture, technologies, institutions)
Normative framework	Individual and social flourishing	Empirically based conceptions of individual wellbeing & human social flourishing
Metrics	Beyond GDP and shareholder value	Multi-dimensional measures of wellbeing and performance, e.g., SAGE, OPHI, OECD Better Life, B Corp Impact Assessment
Political economy & ideology	New political economy	New theories of value creation, distribution, roles of markets, states, and civil society (e.g., Bowles & Carlin "shrinking capitalism", Besley & Chandler "cohesive capitalism", Rodrik "productivism", Beinhocker & Hanauer "market humanism")
Emblematic policies	Policies to align markets with human wellbeing & environmental sustainability	E.g., job guarantees, place-based policies, investments in capabilities, new forms of labor power, balanced stakeholder corporate governance, modern competition policy, green industrial policy, circular economy
Public and political narratives	Middle-out economics; enabling state; freedom to flourish	E.g., from greed is good to cooperation is good; from equality vs merit to fairness; from big trade-offs to big win-wins; from growth to progress

As we have noted, important progress has been made on the bottom values (moral foundations) layer and upper normative layers of such a new ontological stack. We believe that by strengthening and building the scientific layers with tools, methods, and ideas from the complex systems community, that we will begin to see greater coherence across the stack and new insights as to how policies and institutions might better translate the values of a new paradigm into better outcomes in the real world.

[⌗⌗] From a presentation by Brian Arthur to Nanyang Technical University, February 29, 2012

7. Towards a New Paradigm

While there is a long way to go, complexity economics is already contributing novel scientific insights to such an agenda. Much complexity economics work has normative implications for major policy and political challenges, including the function of the financial system (e.g., Poledna & Thurner 2016), economic inequality (e.g., Adamou & Peters 2020), macroeconomics (Wiese, et. al. 2024), economic growth and development (Hidalgo et. al., 2007), climate change (Way et. al. 2022), diversity (Page 2010), political institutions and democracy (Bednar & Page 2018, 2025), political polarization (Bednar 2021), and institutional robustness and adaptability (Bednar 2009).

We should also note that there is potential for this progress to accelerate rapidly in the coming years. Complexity economics methods tend to heavily utilize computing power and data—both of which continue to become exponentially cheaper and more available. And the AI revolution will unlock new possibilities in the development of complexity economics. AI is already being used to accelerate model coding, parameterization, sensitivity testing, data cleaning, analysis, and forecasting. Potential exists to combine AI's with ABMs to create highly detailed and realistic "digital twins" of economic systems with micro level data on all relevant agents (e.g., Axtell 2016) and to explore possible policy spaces (e.g., Agrawal, et. al. 2025).

So, what needs to be done to advance the agenda of new paradigm construction? In our view, there are five priorities:

1. *Scaling the complexity economics community*—The progress that has been made to date has been driven by a relatively small, interdisciplinary community of scholars. There are a few research centers focused on complexity economics including INET Oxford, Harvard's Growth Lab, the University of Vienna Complexity Science Hub, George Mason's Computational Social Science department, and of course the Santa Fe Institute. But most scholars are scattered in institutions around the world and the scale of activity is small relative to more traditional economic research. Robert Axtell of George Mason University roughly estimates that traditional equilibrium based macroeconomic models alone have had about a million person-years of cumulative effort invested in them to date, while complexity economics models across all topics have had something like 100,000 person-years.[§§] Furthermore, additional integration is needed between the complex systems and evolutionary perspectives within the complexity economics community.

[§§] Axtell presentation to Google Modeling Talk Series available on https://sites.google.com/modelingtalks.org/entry/agent-based-modeling-of-economic-phenomena-at-very-large-full-scale

2. *Developing a new welfare economics*—there needs to be more two-way engagement between the complexity economics community with scholars working on the moral foundation layers as well as those working on the normative and policy layers of a new paradigm. In the neoliberal consensus stack, welfare economics provides critical connective tissue between moral foundations, formal models, normative findings, and policy analysis. Such connective tissue is missing in the new paradigm (Beinhocker, et. al. 2023). And many scholars working on these issues are unfamiliar with the complexity economics approach and vice versa.

3. *More interdisciplinary collaboration between economists and the complex systems community* – A new generation of economists trained in empirical approaches, comfortable with computational methods, and interested in tools such network theory, multi-agent models, and AI, presents an opportunity for closer engagement. There are important methodological and scientific issues to be debated between the economics and complex systems communities, but to date that debate and engagement has been limited. Many economists remain unaware of the complex systems literature and complexity researchers would benefit from the deep domain knowledge of economists. The need for new answers at the normative and policy ends of the stack should drive innovation and openness to non-traditional approaches in both communities.

4. *More engagement with policymakers and political leaders* – Some of the most important progress in complexity economics and development of a new paradigm more generally has been driven by the needs of policymakers. For example, since the 2008 crisis there has been significant engagement with complexity economists by central banks (Borsos, et. al. 2025), as well as policymakers working on climate change, labor market policies, trade, supply chains, and other topics. Furthermore, by viewing political systems as networks of people and interconnected institutions, complexity science builds our understanding of the robustness and efficacy of governance structures. By exploring these networks and interdependencies, complexity science can illuminate "sensitive intervention points" where interventions can yield outsize positive outcomes (Farmer et. al. 2019). Complexity science also emphasizes the interconnectedness of political actions and public responses, enabling the design of policies that are not only supported and effective, but also adaptable to future challenges.

5. *Development of new public narratives* – The use of terms from complexity science like leverage points, feedback loops, and interdependence is becoming common in discussions about global issues such as financial stability and climate change. These are no longer just academic terms; they are becoming

part of everyday language for practitioners and the public alike. But we need to go much further in developing compelling narratives that connect the moral foundations of a new paradigm, with scientific insights from complexity economics, and normative calls to action. Such narratives were key to the popular support for and political adoption of the three 20th century paradigms (despite their later failures). Humans are storytelling animals, and a new paradigm needs good stories.

As complexity economics advances, it holds the potential to provide a crucial layer of scientific explanations, connecting moral ideas on what constitutes a "good" or "better" economy, with normative political economy ideas on how the system should be organized and the practical policies, practices, and institutions to get us there. By fostering interdisciplinary collaboration and continued methodological innovation, the complexity economics community could help lead the development of new tools and frameworks that enable societies to better manage the enormous challenges we face in a complex, interconnected world. The failed economic paradigms of the 20th century are not up to this challenge. It is time to build a 21st century paradigm that is.

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