Something Old or Something New?: Complexity Theory and Sociology

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Abstract

Does complexity theory offer novel theoretical and empirical insights into social processes or is it merely a repackaging of sociology's central tenets? This question motivates the following theoretical overview and analysis in hopes to spur further inquiry into social complexity. Complexity theory posits that interaction between social agents produces emergent macro level patterns; a statement which is remarkably consistent with extant sociological theory. Following this line of inquiry, I provide a brief discussion of complexity theory, emphasizing connection with sociological theory. I then attempt to clarify complexity theory by illustrating that it is neither a theory nor a method of research, but instead a meta-theory. In this light, complexity theory can illuminate certain underdeveloped aspects of sociological analysis, such as the importance of initial conditions and non-linear dynamics, enriching our understanding of social phenomenon. The aim, therefore, of this paper is to spur sociological theorizing, far from equilibrium, at the edge of chaos and complexity.

Keywords: Sociological Theory, Complexity Science, Emergence, Theory Development.

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Introduction

Despite the rise and fall of many theoretical research programs over the past century, the micro-macro relationship or structure/agency debate remains central to sociological inquiry while at the same time occupying a tenuous theoretical position. At one end of the spectrum lies agency, while at the other structure with various theoretical traditions privileging one over another. Hoping to resolve the structure/agency debate, scholars have drawn on concepts such as Habitus, structuration, and recently complexity theory (Giddens 1984; Bourdieu 1985; Miller and Page 2007). Indeed, a particular strength of sociology is the insight that individuals are complicit in the production and reproduction of social structure. Recursive social interaction among actors affects both micro and macro level social processes. In this paper I argue that complexity theory holds substantial promise for future sociological research, connecting the micro-dimensions of social action to macro-level social structures. Complexity theory remains, however, a nebulous proposition for sociological analysis. Specifically, extant scholarship remains unclear as to its central tenets and theoretical structure (see Page 2015).

A brief vignette provides an illustrative introduction to complexity theory. Johnson (2002) contends that social and economic preferences partition urban neighborhoods into distinct geographical tracts with unique cultures, such as Greenwich Village and Harlem in New York or Haight Ashbury and Mission in San Francisco. Johnson further states that these neighborhoods arise and

persist for, in some cases, hundreds of years, absent of direction from urban planners or city officials. But how? Schelling's (1971) research provides insight by specifying the necessary conditions that engender residential segregation. Specifically, Schelling's model suggests that people prefer to be near those similar to themselves – an argument of homophily; the slightest preference towards one type of group results in widespread patterns of spatial segregation. Accordingly, segregation emerges from local patterns of interaction among actors who a. observe the environment around them, and b. then decide to move to another location if there are a certain number of dissimilar individuals in their adjacent environment (Schelling 1971; Clark 1991). Schelling's model is an early example of a complex adaptive system in the social sciences and has been influential both sociology and the physical sciences (Clark and Fossett 2008).

At its core, complexity theory emphasizes the emergence of irreducible phenomena as the result of local level interactions among numerous semi-autonomous agents (Miller and Page 2007). As models of residential segregation suggests, certain concepts, such as decentralization, adaptation, and non-linearity represent some of the central theoretical principles of complexity theory. As such complexity theory has been applied to a wide spectrum of physical, biological, and social systems, ranging from the flocking patterns of birds (Reynolds 1987) to the overcrowding of popular restaurants (Zambrano 2004). Interestingly, few sociological studies, outside specialty journals (e.g. The Journal of Mathematical Sociology, Journal of Artificial Societies and Social Simulation, Emergence: Complexity and Organization), or a few articles and books (e.g. Powell et al. 2005; Padgett and Powell 2012) engage and maintain a dialogue with complexity theory. Nevertheless, complexity theory offers great potential to transform sociological theories in a manner that better reflects social reality and provides novel insights into a range of social processes (Page 2015), such as the natural environment (Bowden, 2017), inequality (Tilly 1999), and the dynamics of societal institutions (Clemente, Durand and Roulet 2017) . For example, Brown (1994) illustrates how partisan control of the White House and environmental policy exhibit chaotic dynamics, oscillating between environmental degradation and substantial economic costs. Contrary to expectation, a complexity perspective suggests that to maximize environmental welfare, one possible solution is to shorten the time political candidates' campaign, thereby decreasing the emphasis on appealing short-term answers to attract votes (Brown 1994).

However, one overarching question remains: does complexity theory offer a new and unique lens to better understand the micro-macro relationship and social processes or is the banner of complexity merely a repackaging – albeit in a shiny technological façade – of the most central doctrines of sociology? As an abbreviated answer to this question, this paper argues that complexity theory is neither, but rather a meta-theory that directs attention to important sociological processes – feedback loops, emergence, self-organization, non-linearity. More than merely serving as a metaphor, complexity theory offers a framework to incorporate an array of the aforementioned concepts into unified sociological theories. In this manner, complexity theory can place context around the measurement of variables or the observation of processes and offer a holistic explanation of a given social phenomenon. To more fully answer this question, this paper will first review complexity theory in general, non-technical terms, detailing precisely what it is and what it is not, hoping to provide clarity and coherence to the ambiguous term. A brief discussion of complexity theory in light of the central concerns of sociology will follow, with the goal to spur an increase of sociological research on the complex and chaotic. Finally, I present an example of complexity theorizing by examining the case gendered labor queues, before suggesting further avenues for future research.

Complexity Theory

Emergence is the central concept of complexity theory. A wide range of processes and objects embody the notion of emergence. For instance, a lake, flowers, and lilies emerge from the short, colorful brushstrokes of Monet's *Water Lilies*; the numerous swaths of color interact upon human perception to produce a beautiful image. Also like an impressionistic painting, emergent phenomena are irreducible to their constituent parts, rejecting ontological arguments of scientific reductionism. Specifically, complexity theory posits that macro level phenomenon emerge from the interaction of numerous semi-autonomous agents (Miller and Page 2007; Holland 1998; Kauffman 1995). Two terms deserve attention from the preceding definition: agent and semi-autonomous. First, the term agent is synonymous with actor in the context of social systems (Plowman et al. 2007). Like a national economy (Arthur 1999), complex systems

require interaction from vast quantities of agents, such as firms, banks, investors, brokers, and regulatory agencies. Semi-autonomous indicates that the behaviors and actions of agents are bound by specific rules governing interaction, analogous to the cognitive limits of bounded rationality (Rubinstein 1998) and societal norms. Therefore, interactions between agents are complex, as dense interdependencies among the system's agents gives rise to emergent structures (Miller and Page 2007).

Complexity theory also directs attention to various features of social processes, such as initial conditions, feedback and adaptation. Due to the temporal dimension of complex adaptive systems, initial conditions can exert great influence on system dynamics (Holland 1998). Plowman and colleagues (2007) demonstrates how initial conditions, such as a small, informal breakfast for the homeless can undergo radical non-monotonic change, transforming a formerly minor event into a ministry that feeds, clothes, homes, and provides medical care for thousands of homeless people. Therefore, the magnitude of a variable can increase exponentially between time t and time $t + 1$, rejecting notions of linearity and equilibrium present in traditional sociological theories (Anzola et al. 2017).

Under conditions of interdependent interaction, feedback loops also become important components of complex systems and can fundamentally alter aggregate level behavior (Miller and Page 2007). Feedback loops can either be negative, where "changes get quickly absorbed and the system gains stability" or positive, where "changes get amplified leading to instability" (Miller and Page 2007: 50). Noticeably, negative feedback loops are necessary to curtail the non-linear dynamics often present in complex systems. Feedback occurs between at least two elements of a system, although not necessarily the agents; for instance, in a financial system changes in regulatory policies can alter financial reporting practices and then affect individual interpretations of company performance (Polacek et al. 2012). Furthermore, feedback loops provide paths for information, energy, and resources to flow between agents and across hierarchical levels. Schelling's (1971) segregation model illustrates feedback as agents scan their immediate environment for attributes of nearby agents and incorporate this information into future decisions.

Finally and closely related to feedback loops, the agents of complex systems adapt to their environment. Adaptation occurs through interaction with other agents and feedback flowing from the upper hierarchical levels of the system to the local levels of interaction and vice-versa (Miller and Page 2007; Flake 1998). Generally, adaptation refers to an agent's recognition and response to environmental stimuli and can include learning. For example, adaptation can occur at the conclusion of an emotionally moving orchestral performance; individuals will often stand and clap, once begun other audience members will rise and give applause due to the action of those audience members immediately around them (Miller and Page 2007). Individuals may fear negative social sanctions and applause to avoid them. This sort of adaptive response underlies many theories of social contagion. Therefore, many of the dynamic properties of complex systems originate from adaptation and learning (Flake 1998). This is because the actors in a complex adaptive system must react to learn and adhere to interactional rules and adapt to future environmental changes.

Emergence, interdependent interaction, initial conditions, feedback, and adaptation represent some of the main theoretical concepts of complexity theory; an exhaustive review of every concept, however, is beyond the scope of this paper. The preceding discussion presents a brief overview of what complexity theory is; the next section highlights what it is not.

Complexity Theory is Not a Theory

Although scholars offer a variety of viewpoints about theory, one dominant paradigm within sociological research presumes that theoretical explanation comprises a specific number of systematic requisite statements, specifying the relationships between interrelated concepts through hypthetico-deductive reasoning (Walker 2000; Willer and Webster 1970). In this fashion, theoretical propositions connect initial conditions and abstract concepts nesting these relationships in a manner that allows scholars to make derivations and predictions (Walker 2000). Of particular import, theoretical constructs and concepts represent abstractions of empirical phenomenon or historical observables, such as status, social class, and institutional fields (Willer and Webster 1970). Complexity theory does not, however, adhere to the preceding definition of a theory. The constructs of complexity theory – agents, interaction, emergence, initial conditions – are prone to much of the same criticism as the concept of embeddedness, which is theoretical vagueness, so much so that symbolic meaning and analytical power

are often lost (see Krippner and Alavarez 2007 for a discussion of embeddedness). Indeed, the boundary conditions of complexity theory appear to be non-existent, as scholars apply the paradigm to an increasingly large number of settings. A single theory, for example, cannot account for both the stochastic nature of quantum mechanics and the dynamics of power present in social stratification. Karl Popper offers relevant advice in this regard, "a theory that explains everything, explains nothing." This is not to say that complexity theory is not useful, far from it; however, scholars must take care to use clear and concise theoretical concepts and definitions when discussing complexity.

Complexity Theory as a Meta-Theory

Complexity theory conforms much more closely to meta-theory than to theory. Meta-theory often precedes the construction of formal theory because of the need to address "such fundamental questions as: what is the nature of human activity…? What is the most appropriate set of procedures for developing theory…? What are the central issues or critical problems…?" (Giddens and Turner 1987:162). In other words, meta-theory informs scholars of what to look for and where to look for it. Furthermore, philosophical debates, regarding epistemology and ontology also frequently occur within the umbra of meta-theory, of which complexity theory holds particular promise in reference to sociology. Turner (1990) further argues for the usefulness of meta-theory as a tool for theory building. Meta-theory provides a systematic framework to evaluate and compare various theoretical explanations in an effort to discard irrelevant propositions, and integrate disparate, yet compatible, theoretical arguments (Turner 1990). In this manner, meta-theory serves theoretical progress as both a magnifying glass and a measuring stick for novel theory development and finds useful application to complexity theory.

Following Turner's (1990) instruction, complexity theory can reframe Ridgeway's (1991) status construction theory to highlight and clarify the relationships between variables. For instance, complexity theory posits that interaction (e.g. social exchange) produces emergent phenomenon at varying levels of analysis (e.g. status characteristics among dyads and societal inequality) and frequently reflects the amplification of initial conditions (e.g. initial resource endowment). It is also not difficult to apply complexity concepts to existing sociological theory and this exercise may further efforts of theory development by turning attention to specific understudied variables (Turner 1990). Finally, turning to the philosophical underpinnings of complexity theory reveals the rejection of scientific reductionism, in favor of a holistic paradigm, focusing on the irreducibility of emergent phenomenon. The emergence of societal inequality cannot be deduced from one interaction between two categorically distinct actors, but instead depends of the diffusion of a critical mass of such interactions (Ridgeway 1991).

Complexity theory, as a meta-theory, further emphasizes particular aspects of sociological theory. For instance, Ridgeway (1991) does not give much theoretical weight to the initial distribution of resources besides acknowledging the positive correlation between those resources and the genesis of positive status characteristics. Complexity theory, however, subjects the resource distribution or initial condition to rigorous theoretical analysis, hoping to reveal the nature of the resultant exponential growth of inequality across categorically distinct groups, that interestingly mirrors contemporary work on the top one percent of the income distribution (Keister 2014). Complexity theory also highlights the decentralization of the production and reproduction of market institutions (Diekmann et al. 2014) and the feedback loops present in identity theory (Stets and Carter 2012). Complexity theory, as a meta-theoretical tool (Turner 1990), provides useful theoretical analyses and can illuminate valuable connections and integration between disparate research traditions.

Complexity Theory is Not a Method

Complexity theory typically invokes daunting thoughts of esoteric computational methods, such as programming computer simulations. While agent-based modeling is readily accessible through user friendly software packages, such as NetLogo (Railsback and Grimm 2011), simulations or agent-based models are merely one method that can instantiate and analyze complex adaptive systems. Traditional sociological methods can also usefully investigate complex phenomenon. These include: mathematical modeling, statistical analyses, and qualitative analyses.

Although sociologists may prefer dirty hands to clean models (Hirsch, Michaels, and Friedman 1987), formal mathematical modeling is integral to many sociological theories (Averett and Heise 1987;

Whitmeyer 2003). Formal theory – mathematical proofs and derivations – further refine empirical relationships and permit predictive capability (Skvoretz 2000). Dynamical systems represent one potential form of mathematical models of complex systems. Dynamical systems connect variables through mathematical formulae and provide direction to the flow of resources throughout the system. Valves, throughout the system, introduce feedback loops through mathematical expressions, allowing for the amplification or dampening of a variable's magnitude in accordance to some measure. Due to the deterministic nature of dynamical systems, the method requires an examination of ontological and epistemological assumptions underlying theoretical models; however, it has found use in the political sciences through the use of differential equations to understand voting behavior (Brown, 1993). As such, mathematical models allow for further theoretical refinement and predictive capabilities of existing theory, while also incorporating aspects of complexity theory.

Traditional survey designs and regression techniques can also capture the constantly changing aspects of complex processes. In this light, statistical techniques must be sensitive to the temporal dimension of the event under study. Byrne (1998) provides a methodological tool kit that captures the dynamics of emergence. Byrne argues that the Gaussian or normal distribution is less relevant than other non-linear, non-normal distributions and that analysis should transition from normally distributed variables to other types of distributions, consisting of an iterative, time-dependent approach to arrive at a final statistical model that best fits the data (Byrne 1998). From this perspective, surveys and other traditional quantitative techniques can appropriately investigate complex phenomena with the appropriate methodological tools.

Finally, qualitative methods may also illuminate the dynamics of complex interactions (Plowman et al. 2007; Beck and Plowman 2014). Here, data collection begins by selecting a theoretically meaningful research context (Charmaz 2006), such as a site where radical change recently occurred or, ideally, is expected to occur in the near future. Next, qualitative data from semi-structured interviews and historical data permits the construction of a timeline and provides a perspective on how actors engage with complex process, especially their perceptions, understandings, and actions. Analysis proceeds through the identification of themes in a narrative manner in order to preserve the temporal dimension of the data (see Plowman et al. 2007). Themes then become categories and through close examination between data and theory, new theory arises from the relationships between categories (Beck and Plowman 2014). Qualitative approaches are appealing due to the ubiquities nature of complexity and the difficulty in obtaining quantitative data on such phenomena.

Complexity theory is, therefore, much more than a single technological method of inquiry. Complexity theory is a paradigm or meta-theory that orients what is under investigation, but does not specify how to investigate it. The preceding discussion illustrates that the full complement of sociological tools are available for use.

Complexity Theory and Sociology

Ostensibly, the systems concept is the paradigmatic glue that holds complexity theory together. Unfortunately, outside of sociology, it is often conflated with the longstanding problems of Parsonian functionalism, where each element within the system is believed to promote system maintenance and longevity and be necessary for the continuation of the system (Davis and Moore 1944). For instance, Johnson (2002) argues that complex mechanisms direct Smith's invisible hand so that price matching occurs within economic markets and therefore grocery shelves are stocked for actual demand to ensure the daily functioning of regional economic systems. An emphasis on system preservation is troubling because it mirrors discarded sociological theory and can mire contemporary theory in an incessant dialogue with the past. Fortunately, complexity theory provides guidance to move away from such theoretical quagmires.

Extending Parson's functional perspective, Luhmann's (1984) general systems theory brings sociological theory closer to the boundaries of complexity theory. Luhmann's theory specifies abstract principles that engender autopoiesis or the self-organization of social structures. For example, societal race and gender hierarchies exhibit extreme durability over time, persisting through social movements and legal interventions (Tilly 1999). Although general systems theory suggests that systems remain relatively closed, able to buffer environmental turbulence, Luhmann (1993) directs attention to the concept of self-organization, a major component of complexity theory (Miller and Page 2007). Accordingly, social structures reproduce

themselves over time, importing resources into the system, even reproducing the agency of actors (Padgett and Powell 2012). Luhamnn's other contribution to systems theory in sociology that serves as a precursor to complexity theory is that general systems theory exists at a high level of abstraction. Therefore, an analyst is able to use Luhmann's (1984) theoretical framework to provide clarity to a wide variety of social phenomenon.

Moving beyond earlier systems approaches, many scholars highlight an open systems perspective, acknowledging the illusory nature of boundaries that isolate social systems. Indeed, connectivity between social agents characterizes social systems (Miller and Page 2007). Complexity theory allows for permeable boundaries between the system and the environment and the penetration of outside influences into the system. Furthermore, by acknowledging bounded rationality, complexity theorists recognize that agents cannot always serve the interests of the system, which may, in fact, be irrelevant to local interaction. Moreover, environmental forces can also destabilize the system and increase the likelihood of system failure; for example, government de-regulation removed negative feedback loops, increasing the likelihood of an economic crisis (Fligstein and Habinek 2014). Under the open systems perspective, complexity theory only assumes that there are relationships among elements presently in a system and that outside forces can disturb those relationships; the converse is, of course, also true, but an understudied phenomenon in complexity theory. This assumption largely conforms to contemporary sociological thought. Accordingly, complexity theory does not make a statement that the present elements within a system must remain for the system to function, especially since change is the focus of complexity theory.

Of course, there exists a range of views regarding the systems concept. Some complexity scholars advocate for a strong systems view, where the identification of constituent parts and system adaptation is emphasized. Such perspectives conjure images of functionalism and seem to be more appropriate for the physical world than the social world. Complexity theory, by incorporating open systems concepts, also presents a weak systems view. Here the analyst does not need to identify how a system self-reproduces in a setting devoid of people or social processes, but rather can incorporate concepts such as power, interest, and status. Specifically, as acts of power are often a path-dependent process, connecting present outcomes with past inequities or instances of domination, complexity theory may be able to shed light on how certain actors or objects attain control over others or status in a situation. This weak systems assumption, does not posit that the system is perfectly adaptive and that each component functions for the benefit of the system. Instead, the weak form begins with the observation that there are observable patterns in a society and understanding the recursive social actions that underlie those patterns can be helpful.

Complexity theory also addresses the agency/structure debate within sociology. Complexity theory is in many ways consistent with Giddens' (1984) concept of duality, the simultaneous, recursive constitution of both agency and structure. Within a complex system, structure emerges from the interaction of agents and this emergent structure then influences the agents through positive and negative feedback loops. Complexity theory, therefore, sidesteps the prior philosophical debates within the social sciences (Bryant 1992). Complexity theory only requires the assumption that subjective social action at the local level can be reified into objective structure at the macro level through distributed interaction. The point of connection, however, between the subjective and objective is the threshold or critical mass (Miller and Page 2007), a useful concept already at use in the study of revolutions (Marwell and Oliver 1993). Consider that individual dissent of a political regime simmers in relative isolation hidden from observation until a critical threshold of other dissenters is met, roiling the citizens and spurring radical protest (Epstein 2002). A critical mass or threshold of agent interactions precedes emergence.

Finally, as previously mentioned, much of the promise of complexity theory rests on its emphasis of promoting and popularizing previously underdeveloped concepts in sociological theory. Emergence, decentralization, destabilization, feedback loops, adaptation, amplification, non-linearity, thresholds among others, are concepts that sociological theory indirectly addresses, sidestepping intriguing theoretical implications in the process. A complexity science approach thrusts these concepts from analytical obscurity into the sociological imagination, spurring novel theorizing and enriching empirical analysis.

Of course, sociologists would not argue that the social world is complex; therefore how does complexity theory contribute to sociology beyond merely sensitizing scholarship to various isolated

processes. For example, Stinchcombe (1968) describes feedback loops, much earlier than the advent of complexity theory. The central benefit of complexity theory is that it provides a framework that permits the inclusion of many concepts simultaneously. For example, feedback loops generate perturbations in interactional patterns, resulting in non-linear phase transitions in social networks. Prior sociological theory may address an aspect of such phenomenon, but rarely are able to understand the whole. Some theoretical traditions in sociology, such as critical studies, refute any attempt to import systems metaphors into conceptions of control, power, and domination. Nevertheless, complexity theory may accommodate this perspective by highlighting how power arises from interactions and how that power coalesces into higher levels in society. Therefore, a strong systems metaphor is not necessary to use complexity theory.

I will now turn to an example that illustrate how complexity theorizing can aid in the development of sociological theory.

Example: Labor Market Queuing

I now draw on the phenomenon of labor market queuing and gender discrimination to illustrate the primary arguments of this paper. Beginning in the 1970's, the social organization of work has become increasingly precarious, insecure, and unstable for large segments of the labor force (Kalleberg 2011). However, nowhere is the perilous nature of work more visible than the context of worker displacement. Displacement – job loss resulting from an employer's decisions – engenders significant wage loss and widespread unemployment (Jacobson et al. 1993), often differentially affecting workers on the basis of gender (Koeber and Wright 2006). Queueing theory (Reskin and Roos 1990) provides insight into the unequal outcomes that displaced workers encounter regarding unemployment duration (Koeber and Wright 2006; Mazerolle and Singh 2004). Queueing theory assumes that both men and women seek employment in occupations that are economically rewarding. Employers, however, may give preference to men and discriminate against women in the hiring process resulting in longer durations of job seeking and lower wages for women (Reskin and Roos 1990). For instance, displacement scholars reveal that women and other categorical social groups (e.g. racial and ethnic minorities, older workers) are less likely than men to become reemployed after job loss (Koeber and Wright 2006; Mazerolle and Singh 2004).

The labor market bears a striking semblance to a complex adaptive system. Workers and firms seek to match jobs whereby, workers respond to a firm's wage offerings and offers of employment. Workers seek jobs according to their reservation wage – the minimum wage that they are willing to accept for their labor – and the wage offered by firms. Employers set wages, in part, due to their need for productivity, although wages can also be a discriminatory mechanism that hinders access of those in some social groups to jobs. Through this process, some workers gain jobs while others remain unemployed. In other words, labor market queues emerge from the interactions between numerous workers and firms, they are not an explicit feature of the labor market. This cursory model reflects the core features of labor markets and suggests the following question: What is the minimum conditions which will engender labor queues? To answer this question, I instantiate an agent-based model in the software package, NetLogo. The model is as follows:

Actors

The actors or agents in the model are workers will possess the following four characteristics or variables and rules for interaction:

1. Approximately half of the agents will be female and the other half will be male.
2. Females and males each have a reservation wage that varies.
3. Workers can either be employed or unemployed.
4. The longer workers remain unemployed, the lower their patience for such conditions becomes; therefore, after a period of time workers will reduce their reservation wage in order to increase the probability of obtaining employment.

Firms

The model also includes firms, which hire workers. Firms allocate wages and hiring decisions due to a random function. When agents move over a firm a comparison is made. If a worker's reserve wage is lower than the employer's offered wage, the worker becomes employed at that firm and stops moving. If the reserve wage is higher than the wage offered then

no hiring takes place and the worker continues to randomly move around the environment. An employer can choose to discriminate by adjusting the wages they offer to workers. Firms are shaded gray below.

Figure 1 illustrates the model prior to any interaction. In this experiment, there are 500 workers, 250 of which are male and 250 of which are female. There are also 500 firms. The simulation then runs for 100 iterations. During this time workers become employed as a function of their reserve wage matching an employer's offerings, randomly lose their jobs, and become re-employed. Unsurprisingly, for the initial trial, specifying no bias, there is not a discernable difference between the likelihood a female worker or a male worker will become reemployed. In the preceding example, 33.2% of males are unemployed after 100 ticks and 33.6% of females are unemployed after 100 ticks. This ratio remains very similar across multiple trials and is to be expected as a result of chance. Moreover, some workers have been unemployed for the duration of the experiment because their reserve wage is high, not as the result of discrimination.

For subsequent trials, I adjust the employer's wage offerings to males, higher relative to females. However, there is still no discernable difference in employment patterns across males and females. In some trials more men are unemployed by a small margin and in other trials more women are unemployed by a small margin. Indicating that in the model, a worker's reserve wage does not seem to be an initial condition that undergoes non-linear transformations at small deviations, influencing the entire system. Even moderate levels of discrimination does not result in substantial labor queues. For example, a 10% difference in wages offered to males relative to females only produces a 1% difference in unemployment after 100 iterations (29% unemployed males and 30% unemployed females). However, a preference for male workers shortly beyond a 10% difference engenders substantial labor market queues for females. At a 25% difference, almost no males are unemployed after 100 iterations. Figure 1b illustrates the output of this model.

The preceding simulations reveal how gendered labor queues can emerge from relatively simple properties – namely reserve wages and an employer's discriminatory price setting policies. Labor queues, interestingly, emerge rather slowly at moderate levels of discrimination, becoming stable and sizable at only slightly higher levels. This finding may help explain the persistence of wage inequality and employment discrimination because in the workplace the overt forms of discrimination are mostly eradicated, however the slower, more durable forms of bias remain. Therefore, labor market queues may not be sensitive to initial conditions, but respond non-linearly to moderate levels of discrimination, suggesting a need to investigate discrimination and queuing in more nuanced and fine-grained analyses. In this light, a complexity perspective helps to refine sociological theory by highlighting the essential elements of the theory and also point to interesting future avenues of research.

Figure 1a: Gendered Labor Queues Initial Setup

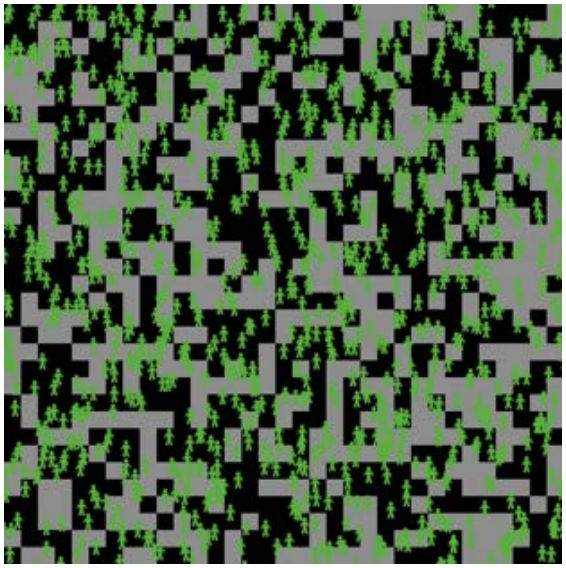
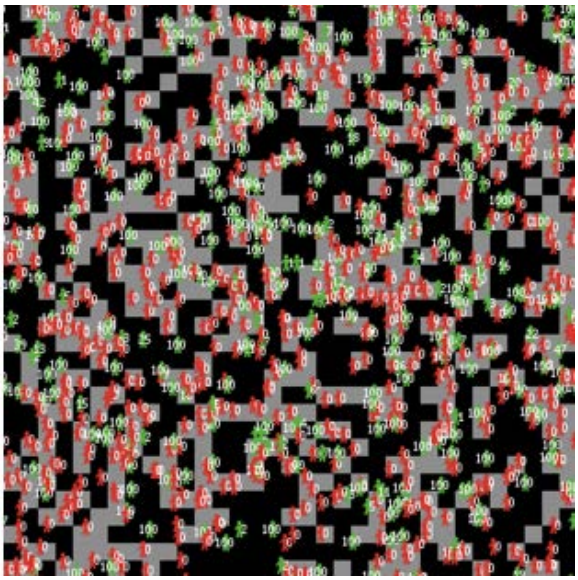


Figure 1b: Gendered Labor Queues Discrimination Trial



Conclusion

Following from the preceding discussion, complexity theory is neither old nor new, but rather a meta-theory that contains many familiar concepts and highlights many more that have previously been in the background of sociological research. Although contemporary sociological theories contain many of the central concepts – emergence, interaction, feedback, thresholds – of complexity theory, a theoretical reformulation emphasizing complex adaptive systems moves the analytical lens of sociology into new directions, encompassing a holistic perspective of such social processes. Furthermore, complexity theory directs future attention to underdeveloped theoretical concepts, such as the importance of initial conditions and non-linearity. As Hao and Naiman (2007: 7) emphasize, "attributes of interest often have skewed distributions" that reject notions of normality. Indeed, interesting sociological analysis often occurs at these extreme edges of a given distribution (Budig and Hodges 2010), yet receives relatively little attention.

In moving forward, researchers may wish to use complexity theory as a meta-theory to gain analytical clarity and cohesion on interesting, yet complex social phenomena. Future research may make use of the wide array of methods for examining complexity. One such avenue includes network analysis, particularly the examination of how networks among interacting agents form and change during the process of emergence (Powell et al. 2005). Barabási and Albert (1999) define complexity within a network through several measures – degree distribution, average path length, and clustering coefficient – that together describe a dense, inter-connected network structure. Network structure allows certain actions to occur. For example, overlapping network structures from distinct social spheres increases the likelihood of innovative outcomes (Padgett and Powell 2012). Moreover, as scholars attempt to determine how best to measure complexity and the potential for non-linear phase transitions, a network perspective offers a useful socio-metric approach. Scholars may observe network connections among, individuals, computers, or firms, to name a few, and note their changes in connections after an event or the passage of time. For example, when viewing the economy as a complex system (Arthur 1999), did economic transaction networks among individuals and firms shift prior to the Great Recession in 2007? If so, how? Sociological research may seek to understand the potential reconfiguration of social networks during phase shifts and explain why changes in network structure occur. Are such changes universal across complex systems or are they unique to social contexts? In this manner, complexity theory would cease to be an imported theory from the physical sciences and begin to assume the trappings of a native social theory. Moreover, answering such questions would allow sociologists to make unique contributions to complexity theory that the natural sciences are unable to do.

Complexity theory also offers a framework that not only specifies various processes that occur across social contexts, but also the temporal dimensions of such processes. Variance theories in sociological research specify intercorrelations among two or more variable's values. However, variance theories rarely postulate when an event may occur, such as a catastrophe. Complexity theory may help to address this issue. For instance, greenhouse gas emissions are a particular concern of environmental sociologists and are related to consumption within a society (e.g. Jorgenson et al. 2018). From a complexity theory perspective, at what level and what duration of consumption precedes a marked change in global temperatures? Therefore, complexity theorizing can add precision to extant social explanations and ensure that social scientists consider not only that a relationship exists between two variables, but also the various contingencies that influence that relationship.
In sum, complexity theory promises to bring a fresh perspective on sociological theorizing. For instance, labor market dynamics and discrimination, as in the

simulation example above, suggest new questions for inquiries when scholars apply a complexity theory approach. Network studies, perhaps, offer the greatest opportunities to refine complexity theory and bring it more fully under the purview of the social sciences, casting away the mere adoption of complexity theory as a metaphor for social processes. There are, however, many exciting new research questions awaiting answers. The aim of this brief paper, therefore, is to spur complex sociological theory development far from equilibrium, at the edge of chaos.

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