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What Are Reflexive Economic Agents? Position-Adjustment, SLAM, and Self-Organization

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What are reflexive economic agents?

Position-adjustment, SLAM, and self-organization

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Abstract: If mainstream economics and its view of economic agents is designed for a world in which reflexivity and feedback processes in the economy are 'tamed' and predictable, how are we to understand economic agents in a world in which reflexivity is 'untamed' and economies regularly exhibit unexpected fluctuations and significant nonlinearities? In a nonlinear world, economies evolve and undergo critical phase transitions from one form of organization to another. It seems, then, that we should also expect economic agents to evolve and undergo critical phase transitions from being one type of agent to another just as we observe that economies evolve and undergo phase transitions from being one type of economy to another. Minsky's analysis of how economies evolve in financial crises and how firms as agents evolve as their financial status changes seems a clear example of this. But then we would need a new conception of what economic agents are. This chapter offers such a conception in the idea of reflexive economic agents, both to redevelop an evolutionary, complexity account of what agents must be and also to forestall complexity researchers from falling back upon the standard utility conception of individuals.

The chapter builds its reflexive agents conception around Herbert Simon's complexity thinking about quasi-independence. It describes reflexive economic agents in what it call position-adjustment terms, and focusing on the 'reflexive moment' when agents find they need to revise and adjust their positions in regard to what they are doing. To explain how we can understand adjustment, the chapter employs the thinking behind recent 'simultaneous localization and mapping' (SLAM) research in robotics engineering to explain how agents understood in position-adjustment terms can be attributed a form of mobility understood as a capacity for self-direction reliant on a kind of locational self-awareness. The chapter then frames the reflexive individual conception that results in terms of Simon's quasi-independence, evaluates this conception in identity terms, and then returns to the issue of why complex economic systems made up of utility maximizing agents cannot function as evolutionary systems. The chapter closes with a discussion of complex systems seen to evolve through phase transitions.

Keywords: reflexive agents, complex systems, position-adjustment, SLAM robotics research, phase transitions, Minsky, Simon

JEL codes: B41, B52, , D91

What are reflexive economic agents? Position-adjustment, SLAM, and self-organization

"A solution to the SLAM problem has been seen as a 'holy grail' for the mobile robotics community as it would provide the means to make a robot truly autonomous" (Durrant-Whyte and Bailey, 2006, p. 99).

1. What view of complexity?

While there are many views of what complex systems are (see Rosser, 2021) that emphasize nonlinearities, phase transitions, and disequilibrium dynamics, this chapter builds on Herbert Simon's classic understanding of what a complex system is (1962). Simon also developed a conception of bounded rationality to explain agent behavior in complex systems, and rejected the utility maximization conception of agent behavior. Left unexplained is what kind of agents, ontologically speaking, operate in complex systems, and how we explain their identities. This chapter takes up this task, and replaces the maximizing idea with a reflexive adjustment idea. The chapter spells out what reflexive adjustment involves in position-adjustment terms, using a stock-flow interpretation of this to explain the identity of boundedly rational agents/individuals in complex economic systems. This conception is illustrated with experience from the 2007/2008 financial crisis. Agent mobility in an uncertain, complex world is then explained using 'simultaneous localization and mapping' (SLAM) research from robotics engineering to explain how agents carry out position-adjustment.

2. First, why *reflexive* economic agents?

Reflexive behavior is adjustment behavior. If mainstream economics and its view of economic agents, then, is designed for a world in which reflexivity is 'tamed' and predictable, how are we to understand economic agents in a world in which reflexivity is 'untamed' and economies regularly exhibit unexpected fluctuations and significant nonlinearities? In a nonlinear world, economies evolve and undergo critical phase transitions from one form of organization to another. Thus, we ought also expect economic agents to evolve and undergo critical phase transitions from being one type of agent to another just like economies evolve and undergo phase transitions from being one type of economy to another. Minsky's analysis of how economies evolve in financial crises and how firms as agents evolve as their financial status changes is a clear example of this. Consequently, understanding the economy as a complex economic system needs to include an understanding of economic agents as reflexive beings, who continually adjust their behavior by responding to the feedback effects of their actions and those they interact with, and who continually evolve as agents as the economy evolves. The goal of this chapter is to set out a very basic account of what a reflexive economic agent is.

I say 'a very basic account' because while there has now been considerable research in economics on complex economic systems, the idea that the agents in such systems are fundamentally different in nature from conventional utility maximizing agents has not been very seriously entertained. Indeed, some complexity researchers may believe economic agents in complex economic systems are really just conventional utility maximizing agents operating in nonlinear environments, and that one needs a fairly conventional type of economic agent to be able to explain how agents operate in unconventional environments. This raises two related questions:

- Might it be for some complex economic systems researchers that reflexive economic agents are really just standard mainstream utility maximizing agents operating in nonlinear environments, perhaps modified only to exhibit some form of bounded rationality?
- Can the analysis and explanation of complex evolutionary economic systems develop as an account of real world economies in the absence of any significant development of thinking about what agents are in such systems?

I am concerned that the answer to the first question is yes, but will argue that the answer to the second question is no. To be fair, when evolutionary system researchers use a utility conception of the agent it may be because it is unclear how reflexive economic agents differ from utility maximizing agents, and also how including utility maximizing agents in their analysis might limit what it can explain. Consequently this chapter's first main task is to set out only 'a very basic account' of what is involved in being a reflexive economic agent. Its second main task is to show how explanations of complex economic systems that include utility maximizing agents become equilibrium systems, cease to be evolving complex systems, and how explanations of complex economic systems require some conception of reflexive economic agents.

What links these two tasks is a general critique of utility function representations of economic agents. I previously argued (Davis, 2011, pp. 6ff; Davis, 2015) that the mainstream economics theorem – the von Neumann-Morgenstern utility function theorem (von Neumann and Morgenstern, 1944) – that says we can assign distinct utility functions to individual economic agents possessing well-defined preference orderings – one of the fundamental principles of mainstream economics – is arbitrary and empty, because it is circular to claim agents are individuated by their 'own preferences.' Thus there is really no account of what actual individual economic agents are in mainstream theory. Then what *does* individuate or distinguish economic agents, especially in complex economic systems in which agents are interdependent in many ways? This chapter uses Simon's complexity thinking about quasi-independence to address this issue, but *en route* I set out an account of reflexive economic agents adequate to a nonlinear world

Section 3 presents the 'very basic account' of reflexive economic agents, characterizing them in what I call position-adjustment terms, focusing on the 'reflexive moment' when agents find they must revise and adjust their positions for what they are doing. Section 4 turns to how we conceive of adjustment, and employs the thinking behind recent 'simultaneous localization and mapping' (SLAM) research in robotics engineering to explain how agents understood in position-adjustment terms can be attributed a form of mobility understood as a capacity for self-direction reliant on a kind of locational self-awareness. Section 5 draws on Simon's thinking about agent self-organization to describe the decision-making behavior engaged in by reflexive agents understood in position-adjustment terms. Section 6 introduces Simon's concept of quasi-independence to address how reflexive economic agents can be individuated and their separate identities understood. Section 7 returns to the questions above to discuss why economic systems made up of utility maximizing agents cannot function as evolutionary systems, and why economic systems function as evolutionary systems when they incorporate reflexive economic agents. Section 8 gives brief concluding comments.

3. A position-adjustment approach to reflexive agents

A complex, evolving economic world is one in which change is pervasive and often unexpected. Since individuals are interdependent in many ways, we should ask, what is it that entitles us to think individual economic agents play distinguishable roles in the economy at all? Let us look at how ecologists and philosophers of biology understand the biocomplexity of ecosystems. Ecosystems are complex webs of interaction operating across many types of organisms, and taking this "ecological structure as the entry point" the key dimensions of biocomplexity are: spatially explicit heterogeneity, organizational complexity, and historical contingency through time (Cadenasso, Pickett, and Grove, 2006, p. 1; also cf. Cadenasso, Pickett, Weathers, and Jones, 2003). In biocomplex ecosystems, structure includes arrays of different types of interacting organisms. Similarly, in complex economic systems, one begins with an "ecological structure" or arrays of different types of interacting economic agents to explain how complex processes work in economies.

The assumption of structure signals the need for a census of what occupies the ecosystem one is investigating – a census which is time-specific and therefore constantly being updated. A census is largely neutral regarding what the nature of the organisms or agents counted is, and on how they manage the effects on themselves of the interaction between them. It simply takes an existing categorical array or classification of agents which may be revised in future censuses. I take this procedural approach to complex systems as an entry point for laying out a 'very basic account' of reflexive economic agents as 'position holders.'

a. Stocks/flows and positions/adjustment

Reflexive agents, then, are simply holders of adjustable positions. One way to get at what this means is to say that a position/adjustment representation of reflexive agents has a similar temporal logic to the standard stock/flow relationship. Agents' positions have the property of stocks in that they are identified at a point in time while their adjustment behaviors have the property of flows in that they occur over time. Just as, that is, agents are always in some position that can be characterized in terms of some set of given, stock-type relationships, so their positions are always subject to change since all stock-type relationships are built around flow-type relationships which sustain or change them. The point is that a position-adjustment framework is similar to the stock-flow relationship in that agents' positions and adjustment behavior are two sides of a single relationship.

The motivation behind this way of proceeding, then, is to build change directly into the conception of the agent by basing the nature of agent on time. Time is one of the most fundamental dimensions of human existence, and the duality of time that the stock/flow idea involves (point in time/over time) is one of our most fundamental ways of thinking about time. Also, since nothing in this representation of time gives an end to time, it follows that agents face genuine uncertainty about the future. Reflexive agents understood in position/adjustment terms, therefore, are necessarily in time and must evolve over time in ways we cannot fully predict.

A second point, then, concerns the nature of the dynamics in the position/adjustment agent conception proposed here. This framework is entirely different from conventional through-time dynamic models in economics, even when formulated in stock/flow terms, for example as in the price-quantity Cobweb model in which some sort of feedback mechanism operates continuously under a set of given assumptions about agents' behavior. Such models are equilibrium models formulated in terms of mathematical solution conditions, which implies that their relationships are specified in such a way that there can be no breakdown, redirection, or change in how they operate in the model. Such models are closed. Reflexive economic systems, however, should be seen as open, evolutionary systems in which feedback processes have real, often unexpected effects that may thus cause agents to act in genuinely different ways, thereby changing how such systems operate. Mathematical equilibrium models rule out evolutionary change emergent upon past circumstances. In contrast, one purpose behind complex systems modeling is to explore how complex systems exhibit phase transitions that are not predictable and so for all intents and purposes are indeterministic. Consider the idea of a 'Minsky moment.'

b. Adjustment and Minsky moments – or reflexive moments

Minsky's financial instability hypothesis represents agents as being in certain types of positions, and then explains the dynamics of these positions in terms of turning points redirecting the agent's course of action (Minsky, 1975). The hypothesis was developed to describe the evolution of firm finance over the business cycle through firms' adoption of increasingly speculative investment positions. When creditors lose confidence in these emergent positions and call in loans or limit finance, a crisis ensues in which firms' positions, represented in balance sheet terms, are no longer sustainable. How the future plays out depends on how firms adjust production and investment in light of this unanticipated change in their economic and financial positions.[1]

Minsky's analysis of crisis highlights point-in-time assessments of agent balance sheet positions that constitute one of the main characteristics of capitalist economies. Property rights determine the rules of balance sheets, but economic agents have considerable latitude in what positions they take within these rules. What positions they take may or may not be sustainable over the course of events. When not, and the effects of failure by a firm or a bank reverberate through an economy magnified across many agents and sectors, as occurred in the 2007-2008 financial crisis, we have a 'Minsky moment,' or a 'reflexive moment' when feedback effects on agents' actions from what they have been doing disrupt the positions they have taken, compelling them to change what they are doing. The events that ensue affecting many interacting agents display emergence as new, unpredicted economic processes evolve from past processes. How, then, do agents understood in this way actually change their positions when fundamentally uncertain about the future. Here I turn to SLAM research.

4. SLAM capacities: self-direction and self-awareness

To begin, note that adjusting a position has both exit and entry dimensions. If only exit explains adjustment, leaving a position, then it is difficult to say we are describing agents, since agents must have some capacity for self-direction. Thus, entry into new uncertain domains somehow needs to be explained. I approach this in a 'bottom-up' way by asking

[1] The balance sheet representation of a firm's position evaluates stocks (in asset and liability terms) relative to their associated flows. An outflow, such as in loan repayments, exceeding an inflow, such as receipts from sales, requires an adjustment in flows, which entails an adjustment in stocks, such as a sale of assets, to rebalance stocks.

how specifically self-directed entry into new domains has been designed to operate in machines on analogy to human self-direction.

a. *Agency as self-direction: SLAM*

Here I address agency as self-direction in a conservative manner according to what seem to be minimal conditions for ascribing some form of autonomy to agents understood in position-adjustment terms. In taking machine design modeled on human capacities as my basis, I draw on what many will surely regard as an unlikely source of such thinking, namely SLAM technology. SLAM is an acronym used in mobile or field robotics research meaning 'simultaneous localization and mapping.' Mobile robots are autonomous or self-directing prosthetic machines increasingly used in hazardous and inaccessible locations to perform tasks that people are unwilling or unable to carry out, such as sub-sea exploration, bomb disposal, shipboard fire and damage assessment, molecular nanotechnology (MNT), lunar and Mars rovers, etc. Prosthetic devices are artificial limbs, and thus SLAM robots are extensions of human powers. The question I am interested in is: what is involved in transferring human powers to such machines, and thus what are the fundamental principles in their design and construction regarding the minimal conditions for achieving self-direction?

SLAM research focuses on one of these self-direction issues, one appropriate to navigating physical space, namely, "the process by which a mobile robot can build a map of an environment and at the same time use this map to compute its own location" (Durrant-Whyte and Bailey, 2006, p. 99).[2] That a robot could have such a capacity is thought to be paradoxical in a chicken-or-the-egg way, since it would need a map to identify its location but would also need to occupy a sequence of locations in order to construct its map. Human beings, of course, have this physical space navigational capacity, and SLAM researchers have sought to replicate it in mobile robots by developing information processing algorithms that when embedded in robots would enable them to simultaneously map their environments as they travel through them. How this works is that as a robot moves through an unknown environment it makes observations of a series of reference points called 'landmarks,' and then estimates how these landmarks are correlated with one another to incrementally construct a consistent – yet evolving – map.

What is interesting about SLAM research regarding the minimal requirements for self-direction is that the solutions to 'simultaneous localization and mapping' problem are formulated in terms of a type of position-adjustment framework. The 'landmarks' are

[2] See the references in this paper for the history of SLAM research.

basically what I have referred to as positions whose interpretation in terms of how they fit on a map of the space they occupy is subject to adjustment as the robot travels across its environment building up its map. What the robot does is peg a 'landmark' or position, given its observations (for example, through cameras and other observational devices), and then recursively revise its interpretation of this position, given successive observations of new 'landmarks' or positions. Thus the robot always exists *in* some location – it always has a 'there' in the world – and it depends on this location as a reference point for its subsequent navigational behavior as a self-directing agent. Similarly, then, I suggest that agents understood in position-adjustment terms navigate an uncertain world by way of mapping revisable sequences of possible 'landmarks' that allow them to make choices about where they will go. Not only is the future emergent, so also is the constantly revised past.

Consider again the experience of households in the 2007-2008 financial crisis. Their economic balance sheet and social positions were in many cases seriously damaged by the subprime housing crash, and, in the 'reflexive moment' that followed, they were compelled to decide how they would adjust their positions. The situation was emergent in that what had occurred with the rise in property values and long decline in incomes left them little understanding of how to proceed. Thus they needed to find new 'landmarks' to map out new positions they could occupy. That past households' experience in the 1930s Depression bore some resemblance to the situation many households now found themselves in meant there existed little-visited landmarks that might now be revisited and reinterpreted in terms of current experience. Perhaps one of the most important lessons for many households from the 1930s Depression was that households had built up debt by over-consuming and under-saving for years. This lesson was thus available to households after the financial crisis, and many households indeed adopted it by paying down debt and delaying consumption. They were thus able to adjust their economic and social positions by re-appraising this unfamiliar past landmark and integrating it into their current maps.

b. Position-adjustment, self-awareness, and the 'self'

Agents understood in position-adjustment terms can be said to be self-directed. What is the 'self' here? In the first instance the 'self' is the agent's position at any one point in time, but since positions are inseparable from the adjustment process through which they may be revised, the 'self' comprehends both position and its possible adjustment. This relatively simply conception of 'self' provides us with a very basic concept of self-awareness for reflexive economic agents. Self-aware agents must be able to recognize the positions they occupy in virtue of their ability to adjust them. Adjustment implies knowing one occupies a position being adjusted, since otherwise it cannot be said to be ‘adjustment.’ This minimal conception of self-awareness is conservative in a number of respects. Being able to recognize and adjust one’s position does not imply anything in particular regarding what the agent understands by that position, or about the medium in which this self-awareness operates, or about whether agents are able to successfully represent or communicate what their own self-awareness involves. These further issues are interesting and important, but I bracket them off in order to emphasize the nature of self-direction in the ‘very basic account’ of reflexive agents proposed here. Different theories of the ‘self’ that address what agents understand by their positions, etc., can then be developed around more specific claims about what agents’ positions and means of adjustment involve.

5. Explaining decision-making behavior: Self-organization

In contrast to biological organisms, economic agents are decision-making agents. If we also see them as self-directed, we also need to explain how they make decisions about the directions they pursue. This subject is of course fundamental to mainstream economics, but my view is that not only are the utility foundations of mainstream theory inadequate for explaining choice, but they also provide a narrower range of choices than can be reasonably attributed to position-adjusting agents. I thus first characterize the space of choice as a combinatorial one to reflect the idea of a wide range of possible choice, and then draw on Simon’s self-organization idea to explain how decision-making agents secure themselves as agents through their response to environmental feedback.

a. A combinatorial space for decision-making

Why agents understood in the position-adjustment approach have a comparatively wider discretion in decision-making is due to such agents are not being defined exclusively in terms of individual-specific characteristics. For example, if we think of preferences as intersubjective, our agent conception can allow that agents could have the preferences of anyone they could reasonably imagine, as in the example of how some U.S. households seem to have responded to the housing crash by adopting the preferences of people two generations earlier. Then, issue is not what psychologically motivates people’s choices – a matter central to the individualist subjectivist view of the agent – but rather what conceptual possibilities are available to people in making their choices – a matter important for understanding the open-endedness of agent expectations and the often unexpected evolution of complex economic systems. How might the space this entails then be described?

A paradigm framework for explaining choice in terms of possibilities in this way is available is Brian Arthur's thinking about choices in technology change (Arthur, 2009). Arthur explains technology change in terms of the idea of combinatorial evolution (cf. Beinhocker, 2011). The more familiar type of explanation of evolution is the Darwinian selectionist account in which offspring get their genetic make-up via lineal descent from their parents. For Arthur, new technologies are always combinations of previous technologies, and this departs from Darwin's in that a technology's antecedents commonly have a wider reach than its immediate parents (that is, similar technologies). What the history of technology development shows is that novel technologies often draw on and bring together entirely unrelated technology streams because an innovator has seen that disparate, even unrelated technology streams can somehow be yoked together to manage our interaction with some natural phenomenon of interest to people. Arthur treats distinct technology streams as different domains of development, and refers to the combination of different technology streams creating new technologies as 'redomaining.' Thus combinatorial evolution as an explanation of evolutionary processes breaks from the relatively confining pathway of lineal descent to project an evolutionary process with vastly greater potential for explaining change than nature and the natural selectionist process accommodates.[3]

When applied to agent decision-making space, this means that that not only are people's choices not constrained by personal preferences, but they also need not be descended in a path-dependent way from 'family' of choice pathways. Beyond saying, however, that people's choices are open, this points toward the possibility of significant discontinuities in patterns of people's choices over time (and perhaps increasingly so). Dynamic mainstream models, as closed mathematical systems, are constructed in such a way as to rule this out by assuming that economic processes converge through negative feedback effects to equilibrium outcomes. Complex real world economies, however, have multiple cross-cutting feedback loops and not infrequently exhibit aggregate positive feedback cycles and crisis events in part because choice behavior is not as tame as mainstream preferences approach supposes. How, then, does this view of wide-open choice fit with the idea of being a reflexive agent?

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[3] Note that since technologies build on technologies, the more technologies there are, the more possible combinations of technologies there are. This implies that not only is technology change cumulative, but that the rate of change is increasing as possible combinations grow exponentially. This is one possible explanation of the much-debated and unexplained take-off in aggregate income in human history, where after income growth was largely flat for tens of thousands of years, it suddenly exploded in the mid-eighteenth century beginning with the scientific revolution in Europe (Beinhocker, 2006, pp. 9ff and Fig. 1.1). Note also that describing technological change in terms of combinatorial evolution does not imply that Darwinian principles do not also operate, as they clearly do in many domains.

b. *Self-organization in position-adjustment terms*

To explain this combinatorial idea in a position-adjustment framework, I follow Simon's bounded rationality (or ecological rationality) theory of choice in which "no 'utility function' needs to be postulated" (Simon, 1956, p. 138). Simon emphasized that agents' cognitive limitations always needed to be understood relative to the structure of environments they occupy, which he also saw as complex and changing (cf. Gigerenzer, 2001, p. 39). To capture how agents dealt with this, he argued decision-makers 'simplified' the decision-making space they faced by setting 'aspiration levels' which they sought to achieve in a 'satisficing' way (Simon, 1955). Aspiration levels are by nature general targets that can 'rise or fall' (if we think along just one dimension) according to the difficulty agents encounter in negotiating their environments. In this regard, he argued that the particular 'behavioral alternatives' agents face (or the range of choices available to them) in pursuit of a certain 'aspiration level' increase with the number of steps taken in pursuing it, and also increase with the degree of persistence agents exhibit in this pursuit. To capture how agents deal with these changing circumstances of choice, Simon used the concept of homeostasis to argue that decision-makers act on the feedback they receive from their environments to adjust their behavior in pursuit their aspiration levels (Simon, 1962). Over a sequence of decisions they then reproduce themselves as evolving decision-making agents who respond to their continually changing environments by employing what they learn from the feedback from their past actions to their new circumstances. That is, they are reflexive, self-organizing agents.

Simon's conception of reflexive self-organizing agents can be interpreted in position-adjustment terms. I accordingly characterize agents' positions as their aspiration levels, where they see themselves as being, and their adjustment behavior as the responses they make to feedback from their past actions in pursuit of their aspiration levels/positions. Reflexive agents on this interpretation are self-organizing agents. They self-organize themselves around their aspiration level/positions via the learning procedure they reflexively employ to deal with change in their environments.

Consider the situation of households before and after the 2007-2008 U.S. financial crisis and housing price crash. Before the crisis, incomes for many households were stagnant or declining. Subprime mortgage finance, however, made it possible for households to temporarily offset weak income by greater house wealth and thereby sustain their household aspiration levels/positions. In effect, households learned that if they adjusted their behavior regarding home finance, they could self-organize their positions in a new way around higher debt levels. When this strategy failed in the housing price crash, households learned how the consequences of their actions fed back onto their positions. Their indebtedness was higher and their houses worth less. With lower wealth, they had little choice but to reduce their spending, though for many this meant they had to self-organize themselves around new, lower aspiration levels/positions. Simon allowed for this in recognizing that aspiration levels rise or fall according to how circumstances change and agents respond. Note again that "no 'utility function' needs to be postulated" to explain this choice behavior.

6. The quasi-independence of reflexive economic agents

At the beginning of this chapter, I noted that the assignment of distinct utility functions to individual economic agents in mainstream economics is arbitrary because it is circular to claim that agents are individuated by their 'own' preferences. Why is this an issue? When you assign a utility function to an agent, the utility function identifies the agent as a distinct causal actor. Obviously it is important in science to properly identify causal agents, and indeed especially important not to mis-identify them if one hopes to produce adequate causal analysis. If one locates agency where it does not exist, then one gets the cause-and-effect story wrong. This issue is mostly ignored in mainstream theory, which assigns utility functions to whatever agents it wishes to assume are causal agents, whether to single individuals or to collections of individuals, without offering any justification of whether they can be regarded as causal agents in the analysis at hand. Good identity analysis, then, underlies good causal analysis in science.[4]

Here, then, I argue that Simon's quasi-independence identity concept successfully distinguishes relatively independent causal agents in complex interdependent domains, such as are investigated in biology and economics. Its advantage is that it explains agents' autonomy relative to both other agents and the environments they jointly occupy rather than in terms of agents' own characteristics alone. Thus it avoids the circularity problem mainstream conceptions of agents have. One important implication of this, then, is that as a relative autonomy an agent's quasi-independence may evolve and may even not endure depending on how the interaction between it and other agents evolves, as suggested above by the experience of U.S. households following the housing price crash.

i. Simon's quasi-independence concept

[4] Why mainstream economics has become so scientifically careless in this regard would be the subject of a lengthy discussion, but most likely three factors are: (i) the simple ideological conviction most microeconomists have that individuals must be shown to be important in economics, (ii) the need to preserve the supply and demand apparatus, which is difficult to sustain without the utility functions and individual demand, and (iii) the mathematical and econometric development of economics since 1950, which has dulled many economists' thinking about science and causality.

A good way to introduce Simon's quasi-independence concept is to look at how biologists have thought about the idea of individuality in nature. Biology investigates how organisms interact and compete for resources in shared ecosystems much like economics investigates how firms and industries interact and compete for resources in the economy. It is interesting, then, that biologists originally treated individual animals as independent causal agents because in Darwinian Theory selection was thought to operate on individual animals (Hull, 1980). However, this theory-based approach to thinking about individuality ignores a variety of other possible 'individuals' in nature that also apparently act as individual causal agents, such as collections of individual animals, like social insect species, and even entire ecosystems made up many different kinds of organisms (Dupré 2002). This suggests, then, that in nature, independence is relative to the extent of interaction an animal has with its environment. If it is 'low,' the animal is relatively independent, and might be considered an individual causal agent; if it is 'high,' the animal should not probably be considered an individual causal agent. Philippe Huneman (2014) adopts this view, and attributes it to Simon. It makes individuality simply depend on the intensity and persistence of interaction between candidate individuals, which Huneman argues can be operationalized in either frequency terms or probabilistically.

Simon's approach derives from his analysis of complex systems as collections of "nearly decomposable" subsystems. A "nearly decomposable" complex system exists where *weak* interactive forces (exhibiting "low frequency dynamics") operate *across* the entire system's set of subsystems, and where *strong* interactive forces (exhibiting "high frequency dynamics") operate *within* each of those subsystems (Simon, 1962, pp. 473-4, 478). The system's subsystems – the domains of strong or high frequency interaction – then possess an individuality Simon terms a "quasi-independence" within the overall systems of interaction they occupy. Subsystems can accordingly be regarded as agents because they constitute relatively independent domains of interaction that both weakly act on other relatively independent subsystems domains, and are weakly acted on by other relatively independent subsystems domains.

What this analysis offers to the position/adjustment conception of reflexive agents is its representation of the agent as a *domain of strong interaction*. The position/adjustment conception of the agent, it should be clear, is a system of interaction involving a dynamic between agents' positions and their adjustment. Agents' adjustment of their positions alters their positions, and their new positions create the possibility of further adjustments, and so on. When we turn to interactions between agents – for Simon, *a domain of weak interaction* between subsystems – we investigate how between-agent interaction produces adjustment in multiple agents' respective position/adjustment subsystems. Simon's purpose in explaining complex systems in terms of "nearly decomposable" collections of subsystems is to show how strong and weak interactive forces are related to one another.

In position/adjustment reflexive agent terms, this is a matter of showing how weak, between-agent interaction is related to a strong, within-agent position/adjustment dynamic.

Let me illustrate how Simon's "quasi-independence" or weak individuality concept has been used (implicitly) to account for the individual identity of the Coasean conception of the business firm (Coase, 1937). A business firm is an individual agent actually made up of the many interacting individual agents who work in the firm. It can thus be regarded as a relatively independent subsystem of strong interactive forces associated with all the non-market interactions between firm members. Firms, or subsystems, then interact with one another in market transactions which for Simon are explained as weak interactive forces. Thus the Coasean business firm is essentially a quasi-independent economic agent. Moreover, since for Simon weak and strong interactive forces are still related to one another, it follows that the behavior which individuals exercise within firms both conditions and is conditioned by the interaction between firms and the behavior of individuals in other firms. Firms are thus relatively independent but also dependent on one another, and thus Coasean firms operate in a complex systems environment.

ii. Identity conditions for the position-adjustment conception of reflexive economic agents

Here I briefly apply Simon's quasi-independence criterion to the position-adjustment conception of reflexive economic agents to determine whether it successfully provides a conception of an individual economic agent. I argued above that for Simon the behavior of reflexive agents can be understood in terms of the idea of self-organization. A reflexive agent adjusts to feedback from its environment in such a way as to homeostatically maintain itself over time as a succession of positions and adjustments across those positions. Is such an agent in effect a subsystem of strong interactive forces akin to the Coasean firm?

I also characterized the position-adjustment conception as an agent conception in which the characteristics of agents are not individual-specific. An agent's position places the agent on a map in a public space. If one were then to think of preferences as motivations, an agent's preferences could include any preferences from the space of preferences, as in the suggested example of U.S. households and saving and spending values from an earlier generation. Indeed in principle agents could entertain as many different types of bundles of preferences as they are able to find in defining their own positions. Suppose we label these different possible bundles of preferences agent's possible multiple selves, since those bundles can be associated with other agents who may have them. Then reasoning counterfactually (Davis, 2018), every agent is itself a subsystem of interaction associated with the different preference bundles or multiple selves they have adopted or could adopt.

Should we characterize agents' multiple selves as subsystems of interaction exhibiting strong or weak interactive forces? My answer is that as a system of interaction tied to motivation to act they involve strong interactive forces by comparison with the weak interactive forces that exist between agents, whether in in markets or other interactive domains. In effect, motivational differences are fine-grained in that small distinctions can bulk large in the possible actions they motivate. This describes strong interaction, whereas distinctions between the different things people actually do are coarse-grained, and thus better describes weak interaction. Accordingly it seems Simon's quasi-independence idea works in a reasonable manner for the position-adjustment conception of reflexive economic agents, entitling us to thus say that agents can indeed be individuated as quasi-independent.

I have employed two criteria – individuation and re-identification – to explain agent identity in economics (Davis, 2011), and Simon's quasi-independence idea only directly concerns the first criterion. Are position-adjustment reflexive economic agents, then, also re-identifiable as quasi-independent individuals through change? On one level, quasi-independent individuals in Simon's framework are automatically re-identifiable as quasi-independent individuals, because they acquire their status as independent by homeostatically responding to change in the form of feedback from their actions. That is, Simon's framework collapses my two criteria into the first. Thus, as long as agents adjust to their environments in the way he explains, they are re-identifiable as distinct agents in virtue of their capacity to do so. Nonetheless, clearly agents understood in this way evolve, and are thus not the same agents over the course of an evolutionary history in terms of the contents of what makes up their identities. On this second level, reflexive economic agents are clearly not re-identifiable as the same agents over time. We might accordingly say that the position-adjustment view provides a dual conception of agents as both changing and not changing. This has interesting implications for public policy in connection with the rights of individuals, but here I simply note that position-adjustment reflexive economic agents are in the sense discussed can be both individuated and re-identified as agents.

7. Evolutionary systems with utility maximizing agents?

Here I argue that explanations of complex economic systems that include utility maximizing agents become equilibrium systems and cease to be evolutionary systems, and that explanations of complex economic systems require some conception of reflexive economic agents. These two claims are two sides of the same issue, nonetheless I separate the discussions below since the first is built around a critique of the utility maximizing agent conception, and the second around understanding evolutionary systems.

i. Why utility maximizing agents cannot be included in evolutionary systems

The utility maximizing agent conception has two main problems from the perspective of evolutionary systems analysis. The first, the 'own preferences' circularity problem, was discussed briefly above. In their standard axiomatic definition (completeness, transitivity, etc.), preferences lack any reference to *who* might have preferences. Thus additional reasoning is needed to say why an agent of any kind has a particular set of preferences – a reasoning ignored in the circular assignment of 'own preferences' to individuals. This means that were agent preferences thought to play a causal role in an evolutionary system, the explanation of that role would be arbitrary. You cannot say that an economy is driven by the action which discrete bundles of individual preferences might have if you cannot say what the bundles are or how the world is carved up into such bundles. Moreover, given that by definition preferences lack any reference to *who* might have preferences, there is in principle no way to determine how preferences get bundled for single individuals or collections of individuals. Preferences as understood in mainstream theory are barred from having any assignment features. Thus the first problem is that economic systems of any kind cannot be explained with utility maximizing agents.

The second problem is specific to evolutionary theory. The preferences of utility maximizing agents are given and exogenous. Where their preferences come from is not determined, but there are two ways such agents might be thought to operate in an evolutionary system. On the one hand, it could be said that in an evolving economy agents' preferences change and evolve from one period to the next. Yet because agent preferences are given and exogenous in any period, this change could only occur through some undefinable mechanism. So this strategy irretrievably puts aside a fundamental concern of evolutionary reasoning, namely, how feedback mechanisms work in complex economies, in this case on agents.

On the other hand, one could alternatively say that agents' preferences do not change or evolve from one period to the next, or that their utility functions are stable despite evolutionary change in the economy. While this is counter-intuitive to the idea of what an evolving economy involves – that it includes domains where no change occurs – there is an even more damaging implication of this strategy for evolutionary reasoning. The behavior of utility maximizing agents is convex, meaning that it always exhibits diminishing returns to any activity. Put differently, the behavior of utility maximizing agents always exhibits negative feedback, never positive feedback. This then runs counter to what most evolutionary reasoning assumes, since positive feedback cycles are one of the principal ways of understanding transformative change and how economic systems evolve. Thus, it seems fair to conclude that utility maximizing agents cannot be successfully included in explanations of evolutionary systems.

ii. Why complex economic systems require reflexive economic agents

Following Simon, it was argued above that reflexive economic agents possess some sort of capacity to adjust to the feedback they receive from their environments and self-organize themselves as agents in the process. Such agents can be re-identified over time in terms of this capacity but not in terms of the contents of their identities. An advantage of this dual conception from the point of view of evolutionary reasoning is that it allows us to refer to agents in evolutionary systems who are both transformed by evolutionary processes and nonetheless remain distinguishable independent agents in those systems. Utility maximizing agents lack this dual nature, but it worth noting that 'agents' thought to be fully evolutionary – that is, changing in all possible respects – also lack this dual nature. Indeed, it is not clear how 'agents' which could evolve in any and all respects could still be regarded as agents since it is not clear why they should not be fully subsumed in evolutionary processes. I leave aside whether evolutionary economic systems can be explained without any reference to agents, and focus on what a position-adjustment conception of reflexive economic agents offers to explanations of evolutionary economic systems.

First, the position-adjustment conception as set out above allows for 'reflexive moments' or breaks in a process when agents genuinely change what they are doing. A property of evolutionary systems is that they are indeterminist in that their pathways cannot be predicted from the past. Darwinian selection explains this for the biological world in terms of unexpected matches between random genetic variation and properties of the environment. However, this sort of explanation does not account for the speed of change in economic systems, and so we need another principle of variation to account for evolutionary economic change. The main candidate in evolutionary economics has been the Schumpeterian 'creative destruction' account of innovating agents, though what such agents are has not been systematically developed. I suggest, then, that the position-adjustment agent conception, which emphasizes the role of 'reflexive moments' in the behavior of such agents provides this further principle of variation.

Second, the character of the 'reflexive moment' treatment – that following Arthur it makes the space of decision-making open in a combinatorial sense – means that positive feedback cycles are not unlikely. Quite the contrary, in dramatic changes in the functioning of an economy, such as emerged in the U.S. subprime crisis, the adjustment agents undertake can lead to a self-reinforcing sequence of actions that become path-dependent and locked-in. Evolutionary systems analysis employs positive feedback cycles and path-dependency explanations, but often do not explain how agent behavior is involved. My view, then, is that if evolutionary economic systems are to be explained with reference to agents, this can be done effectively by moving from aggregate phenomena such as positive feedback and path-dependency to what types of agents would need to be assumed for these phenomena to exist. Agents seen as able to adjust their positions, sometimes dramatically, fits this general view of evolutionary systems.

8. Closing comments

This chapter was motivated by the two issues. First I hypothesized that some complex economic systems researchers might be disposed to thinking in terms of utility maximizing agents because no alternative agent conception appears available. The main part of this chapter was devoted to providing an alternative conception. Second, I suggested that one cannot explain the performance of complex economic systems as evolutionary systems using the standard utility agent conception, but is helped in doing so with a reflexive agent conception, as in the case of my position-adjustment view. Other views of what reflexive agents are could also be used for this purpose.

Thus my general view is that an under-investigated domain in evolutionary complex systems research is the nature of economic agents in such systems. My starting point is that they are reflexive in nature, and that one needs to examine what this involves. Despite the contributions of leading contributors to complex systems thinking such as Simon and Arthur, this terrain is relatively uncharted. This chapter aimed to navigate these few 'landmarks' to advance such a conception.

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